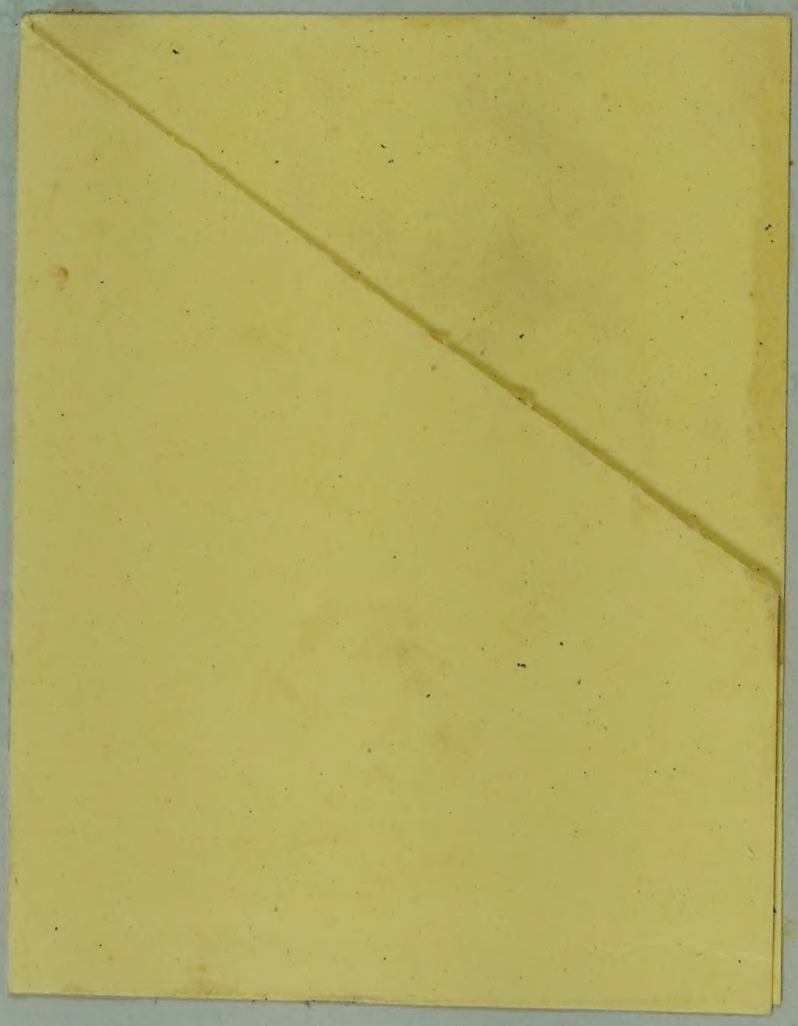
WORLD HEALTH ORGANIZATION
EXPANDED PROGRAMME ON IMMUNIZATION

TRAINING FOR MID-LEVEL MANAGERS

MANAGE THE COLD CHAIN SYSTEM



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MANAGE THE COLD CHAIN SYSTEM

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MANAGE THE COLD CHAIN SYSTEM

Introduction

The cold chain is a system for distributing vaccine in a potent state from the manufacturer to the actual vaccination site. The cold chain system is necessary because vaccines are sensitive to heat. If they are exposed to heat, they will have a shortened life. Some vaccines are more sensitive to heat than others. The following vaccines are listed in order of heat sensitivity. Polio vaccine is the most sensitive to heat, while tetanus vaccine is the least sensitive.

Polio
Measles
DPT
BCG
Tetanus

When vaccines lose their potency, they can no longer protect individuals from disease. Vaccine that has lost its potency is useless.

Vaccine potency cannot be regained once it is lost. Returning vaccine to the refrigerator or freezer will not restore potency.

In general, if vaccines are kept at recommended minimum temperatures, they will remain potent for a long period of time. Figure 1 on page 2 shows these recommended storage temperatures and storage times at various levels of the immunization activity.

If vaccines are exposed to temperatures above those recommended in Figure 1, they can lose their potency rapidly. For example, measles vaccine kept at $+5^{o}C$ will maintain its potency for at least two years. But that same measles vaccine exposed to $+40^{o}C$ will lose its potency in less than one day.

The essential elements of the cold chain system are:

- people to organize and manage the vaccine's distribution;
- equipment to store and transport vaccine.

The importance of people in the cold chain cannot be stressed enough. Often the cold chain is thought to refer only to the refrigeration of

vaccine. Even if the finest and most modern equipment and transportation are available, the cold chain will not be effective if people do not properly handle the vaccine.

Figure 1. Vaccine Storage Times and Temperatures

Type of Vaccine	Regional Store	Transport to Health Centre	Health Centre	Outreach Unit
Oral Polio Measles	Up to 3 months at $-20^{\circ}C$	$-20^{\circ}C$ to $+8^{\circ}C$	Up to 1 month at $+4^{\circ}C$ to $+8^{\circ}C$	Up to 1 week at $+4^{\circ}C$ to $+8^{\circ}C$
BCG	Up to 3 months at $+4^{\circ}C$ to $+8^{\circ}C$	$+4^{\circ}C$ to $+8^{\circ}C$	Up to 1 month at $+4^{\circ}C$ to $+8^{\circ}C$	Up to 1 week at $+4^{\circ}C$ to $+8^{\circ}C$
DPT* Tetanus*	Up to 3 months at $+4^{\circ}C$ to $+8^{\circ}C$	$+4^{\circ}C$ to $+8^{\circ}C$	Up to 1 month at $+4^{\circ}C$ to $+8^{\circ}C$	Up to 1 week at $+4^{\circ}C$ to $+8^{\circ}C$

* Remember: Never freeze DPT or Tetanus vaccine. Keep diluent with vaccine in refrigerator if there is space. If not, refrigerate at least the diluent needed for the following day.

To manage the cold chain system, you must be sure that the following activities are adequately performed throughout the length of the cold chain:

- Obtain vaccines.
- Maintain equipment.
- Maintain vaccines.
- Maintain cold chain

The specific tasks involved in these activities will vary according to the point along the cold chain at which they are performed.

STATEMENT OF PURPOSE

In this module you will practice skills which will assist you in performing important activities in the cold chain system for which you are responsible.

COLD CHAIN SYSTEM

The cold chain consists of a series of transportation links during which adequate refrigeration is required to maintain vaccine potency. For most immunization programmes, these links will be similar to those in Figure 2. The risk of cold chain failure increases as the vaccine moves along the cold chain from the manufacturer to the mother or child receiving it.

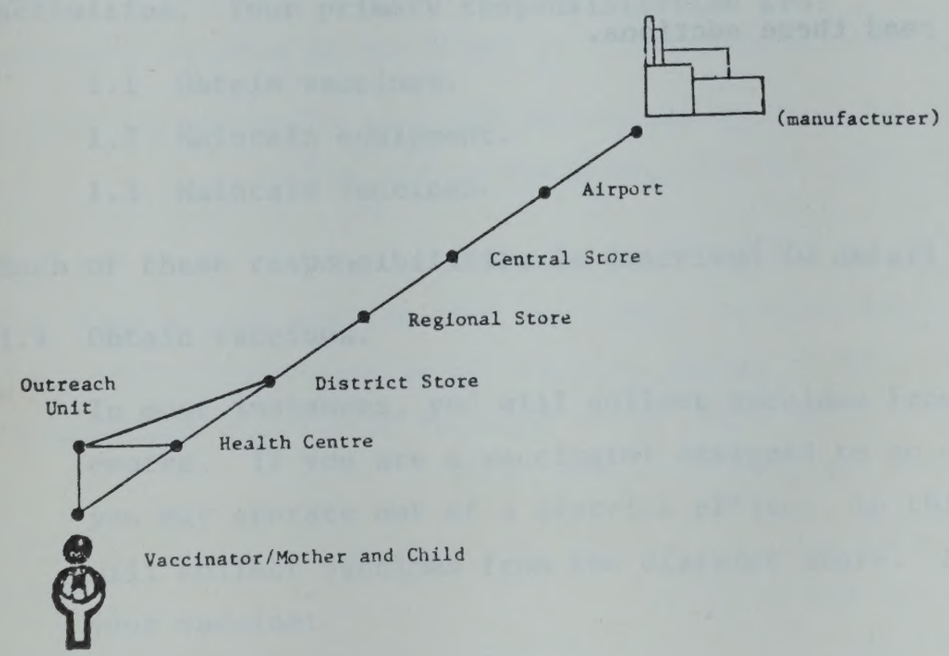


Figure 2.

This module describes in detail the most important activities to be performed at the following links in the cold chain:

1.0 Vaccinator

2.0 Health Centre

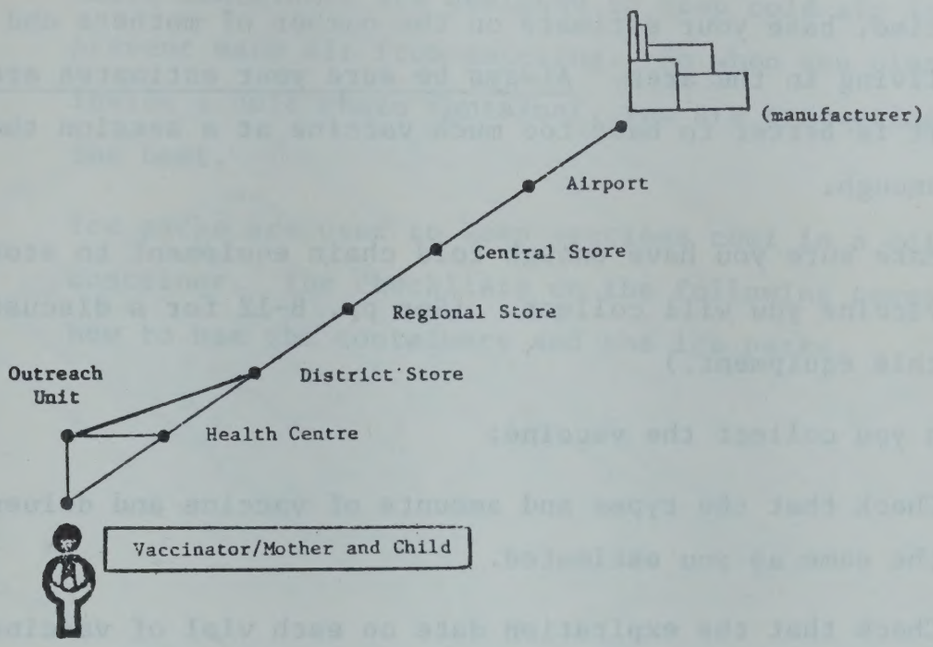
3.0 District/Regional Store

Each section is written for the persons responsible for managing the cold chain activities at that particular link.

The Vaccinator (1.0) is written for the person who actually administers vaccine to mothers and children. Everyone should read this section. If you administer vaccine, it will be of direct interest to you. If you supervise vaccinators, it will help you assist them with their work.

If you are responsible for the cold chain in a health centre or if you administer vaccine through outreach activities, section 2.0 will be of direct interest to you. If you work in a district or regional store, you will find both sections 2.0 and 3.0 helpful. Anyone else who is interested may read these sections.

Sections 4.0 (Central Store) and 5.0 (Airport) provide only brief outlines of the cold chain activities performed at these levels, since most of the people using this module may not be involved in these activities. Anyone who wants to may read these sections.



1.0 VACCINATOR AND THE COLD CHAIN

The risks of cold chain failure are greatest at the vaccinator level. For this reason, as a vaccinator, you are the most important link in the cold chain. You are the individual who actually administers vaccine--either in health facilities or through outreach activities. Your primary responsibilities are:

1.1 Obtain vaccines.

1.2 Maintain equipment.

1.3 Maintain vaccines.

Each of these responsibilities is described in detail below.

1.1 Obtain vaccines.

In most instances, you will collect vaccines from the health centre. If you are a vaccinator assigned to an outreach unit, you may operate out of a district office. In this case, you will collect vaccines from the district store. Before you collect your vaccine:

- Estimate the amount of vaccine you will need. This number will usually be based on previous experience. However, if

the vaccination session is being scheduled for the first time, base your estimate on the number of mothers and children living in the area. Always be sure your estimates are generous. It is better to have too much vaccine at a session than not enough.

- Make sure you have enough cold chain equipment to store the vaccine you will collect. (See pp. 8-12 for a discussion of this equipment.)

When you collect the vaccine:

- Check that the types and amounts of vaccine and diluent are the same as you estimated.
- Check that the expiration date on each vial of vaccine has not passed.

  If the date has passed, do not accept the vaccine unless specifically instructed to do so by your supervisor.

If you are going to an outreach site:

- Pack the vaccine and diluent into the cold chain container quickly but properly. (See pp. 8-9 for a description of how to pack vaccine.)
- Keep vaccine containers in the shade as much as possible.
- Take vaccine and diluent to the site using the shortest route, and cover the distance quickly, but safely.

1.2 Maintain equipment.

Vaccine and diluent taken from cold storage can be kept cold for several days if packed properly in well-insulated cold chain containers. To do this, three types of cold chain containers are available for your use. They are:

A cold box
A vaccine carrier
A flask

These containers are designed to keep cold air inside and to prevent warm air from entering. So when you place vaccines inside a cold chain container, you are protecting them from the heat.

Ice packs are used to keep vaccines cool in a cold chain container. The checklists on the following pages describe how to use the containers and the ice packs.

COLD BOX

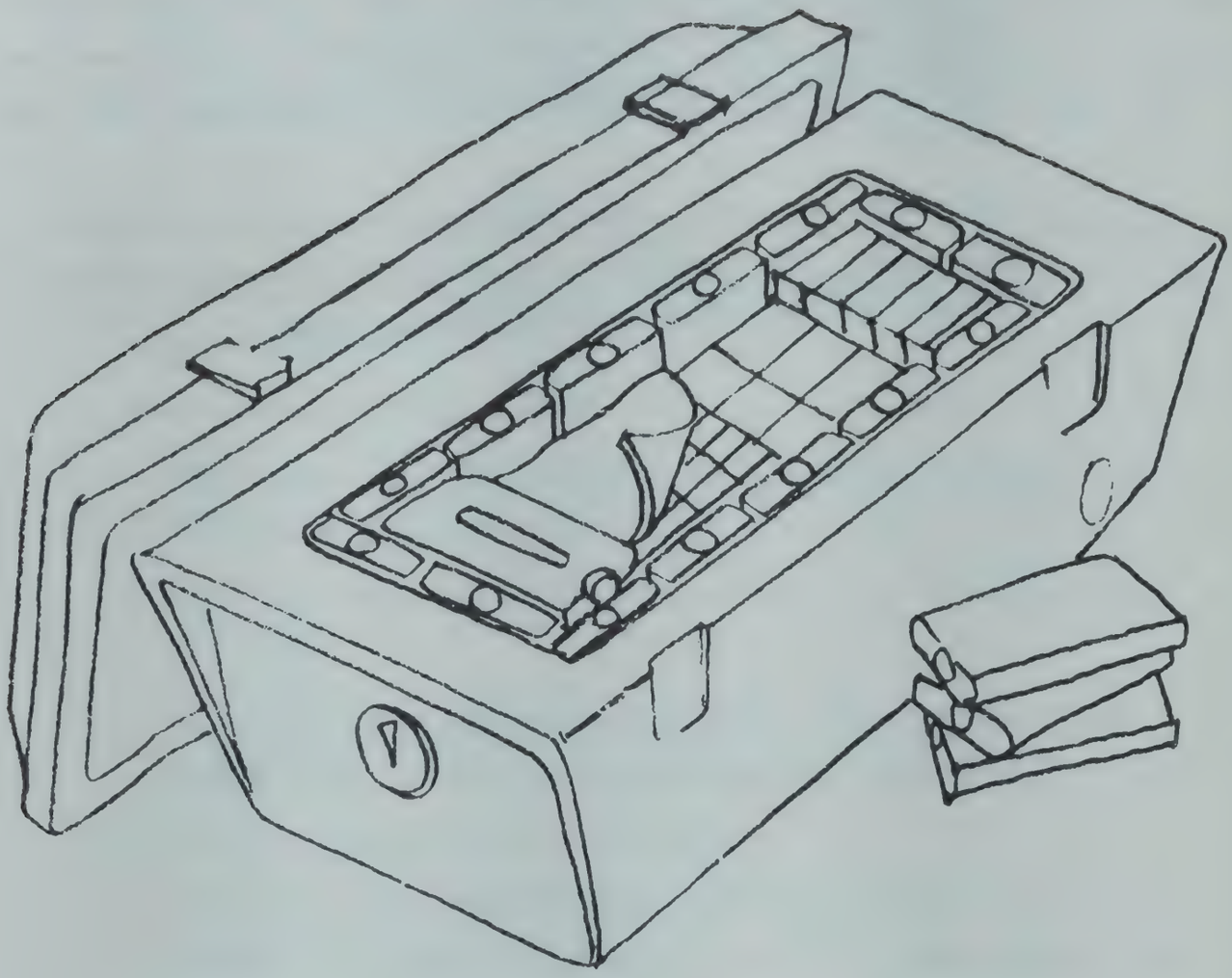


Figure 3. Vaccine Cold Box

Use to:

- Collect large quantities of vaccine from health centre
- Transport large quantities of vaccine by vehicle to outreach sites
- Carry vaccine for several days

To pack:

- Place fully frozen ice packs side-by-side against the inside walls and floor of the cold box.
- Stack vaccine and diluent in the box.
- Place plastic foam or packing material between DPT vaccine and the ice to prevent vaccine from becoming frozen.

- Place ice packs over the top of the vaccine and diluent if there is room, so the vaccine is completely covered.

- Place a small bag of ice blocks on top of the ice packs. These ice blocks will be used to keep vaccines cool during vaccination session.

- Secure the lid tightly.

To keep in good condition when not in use:

- Leave the lid open after each use so that the inside will have a chance to dry out.

- Examine inside and outside surfaces after each use for cracks; repair immediately.

- Paint outside surface white when it becomes dull or worn.

- Check that the rubber seal around the lid is not broken; if so, replace it immediately.

- Adjust the tension on the latches so that the lid closes tightly.

- Oil hinges and locks routinely.

To monitor temperature:

For cold boxes or carriers with a cold life of one week which are being used by mobile teams in the field, dial and probe thermometers can be fitted through the insulated wall of the container (see Figure 4). They provide warning that the ice in all the icepacks has melted and that the temperature is no longer steady. The temperature will rise at approximately 1 to 1.5°C per hour when the ice has melted, and this early warning enables the 5 hours or so after the ice has melted to be used to find more frozen icepacks.

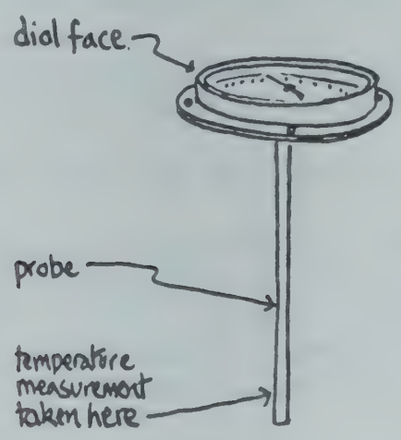


Figure 4

VACCINE CARRIER AND FLASK

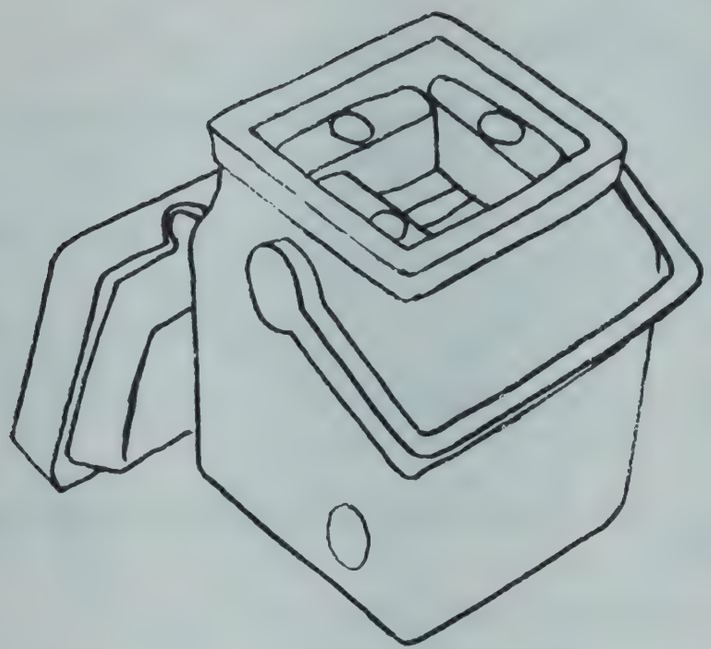


Figure 5. Vaccine Carrier

Use to:

- Collect small quantities of vaccine from health centre
- Transport small quantities of vaccine by vehicle, by bicycle, or by foot to outreach sites
- Carry vaccine for only one day

Note: Use a flask only if a vaccine carrier is not available. A flask is an insulated container, often round in shape like a bottle, which is not primarily designed to carry vaccines. Flasks tend to break easily, and may not be sufficiently insulated.

To pack:

- Place fully frozen ice packs around the inside walls of the carrier or flask.*
- Stack vaccine and diluent in the carrier.
- Place plastic foam or packing material between DPT vaccine and the ice to prevent them from touching.
- Place ice packs over the top of the vaccine and diluent if there is room.
- Secure the lid tightly.

*Note: If ice packs do not fit inside carrier or flask, place vaccine and diluent into carrier first. Then place blocks of ice sealed in plastic bags on top.

To keep in good condition when not in use:

- Leave the lid open after each use so that the inside will have a chance to dry out.
- Clean inside after each use.
- Examine inside and outside surfaces after each use for cracks; repair immediately.
- Paint outside surface white when it becomes dull or worn.
- If adjustable latches are used to fasten the lid, adjust their tension so that the lid closes tightly.
- Keep plastic carriers out of direct sunlight, as this will heat them and may cause the plastic to warp or crack.
- Do not drop carriers and flasks as this can damage them.

ICE PACKS

Use to:

Keep vaccines cool in cold boxes, carriers, and flasks

To keep vaccines cool with ice packs:

- Freeze pack completely.

  If your pack contains 1/2 litre of water, freeze it at least the following length of time before using:

Type of Freezer	Days
Freezing compartment of gas/kerosene absorption refrigerator*	2
Freezing compartment of domestic electric compression refrigerator*	1
Electric freezer	1-2

- Pack ice packs closely in cold chain containers.

- Check for leaks; throw away packs with holes if they cannot be repaired.

- If there is room, keep spare ice packs on the lower shelves of front opening refrigerators. This will help the refrigerator remain cool in the event of a power failure.

Note: You need not rely on commercially produced ice packs. Plastic bottles of water can be used just as effectively.

*Do not put more than 6 ice packs at one time in the freezer compartment. Wait until they are frozen before adding new ice packs, otherwise the temperature in the refrigerator will rise too fast.

1.3 Maintain vaccines.

When administering vaccine to mothers and children at the vaccination site, you must take great care not to expose the vaccine to heat and sunlight more than is absolutely necessary. To do this:

- Select a vaccination site that is as cool as possible, preferably inside a room. If a room is not available, vaccinate in the shade. Do not vaccinate in the sunlight.
- Remove vaccine and diluent from the vaccine container ONLY when you need it.

  Take only one vial of one type of vaccine from the container at a time. Do not take the second vial from the container until it is needed.
- Open the container only when necessary.
- Secure the lid tightly after opening.
- Wrap the vials in silver foil to protect them from heat and light.
- When you take vaccine out of the container, place vials inside a cup containing water and blocks of ice. If the ice melts and no mothers and children are waiting, put the vials back into the cold chain container until a mother does arrive. Then place the vials inside the cup with new water and blocks of ice.
- When your vaccination session is completed, return all vials to the health centre store.

  - Place opened vials in plastic bag.
  - If ice packs in the cold chain container still contain solid ice, mark unopened vials in some way (scratch the label or mark it red) and return them to the refrigerator. Be sure to use these marked vials during the next vaccination session.

- If the ice in the cold chain container is completely melted but has been melted for less than one day:

  Destroy all measles and polio vaccine, so that no one else can use it.

  Mark the remaining DPT, Tetanus Toxoid, and BCG vaccine, return it to the refrigerator, and use it during the next vaccination session.

- If the ice in the cold chain container is completely melted, but for more than one day, throw away all vaccine.

- Do not take the same vial of vaccine out to the field more than three times. If a vial of vaccine has been taken to the field three times, destroy it whether it has been opened or not.

- Keep a record of the vaccine you administer. You can do this by:

  - Entering on a tally card each day the amount of vaccine you collect from the health centre and the amount you return.

  - Collecting the empty vials in a plastic bag and counting them at the end of each month.

- Complete a form similar to the one in Figure 6, on the next page, after each vaccination session. Give the form to the health centre supervisor when you finish the vaccination session or when you return to the health centre.

VACCINATION REPORTING FORM

Signature: _____ Dates: from _____ to _____

Place: _____

Vaccines \ Age group (in months)	3-5	6-8	9-11	12-14	Other children	Pregnant women	Vaccine Information				
							Doses per bottle	Number of bottles	Total doses supplied	Doses administered	Doses not administered
BCG											
DPT I											
DPT II											
DPT III											
Polio I											
Polio II											
Polio III											
Measles											
Tetanus # 1											
Tetanus # 2											
Other											

Figure 6 (Sample)

Exercise A

Instructions: The course manager will set up a practical exercise so that you and other members of your group can practice what you learned in this section of the module. Let your course manager know when you are ready to begin this exercise.

Exercise B

Instructions: Read the following situation and answer the questions below. Write your answers in the space provided after each question.

Situation: Two months ago you administered measles vaccine to 37 children in Village "X" who were 9-12 months of age. Today you hear that in the past three weeks there have been 12 cases of measles and 2 deaths in Village "X" among these vaccinated children. This has been confirmed by an epidemiologic investigation. Your supervisor has determined that the vaccine was potent when it was issued to you. But clearly, some vaccine was not potent when it was administered.

Questions: 1. What are five likely causes of this problem?

2. How would you try to prevent this problem from occurring again?

Exercise C

Instructions: Read the following situation and answer the questions below. Write your answers in the space provided after each question.

Situation: The frozen ice packs in your cold box melt within two hours.

Questions: 1. What are five likely causes of this problem?

1. Vaccine box Kept in sun
2. Opening the box frequently
3. [illegible]

2. How would you try to prevent this problem from occurring again?

- throw away all ice packs + [illegible]
- [illegible] only the necessary
- Avoid direct sunlight
- Keep vaccine in dup [illegible]

Exercise D

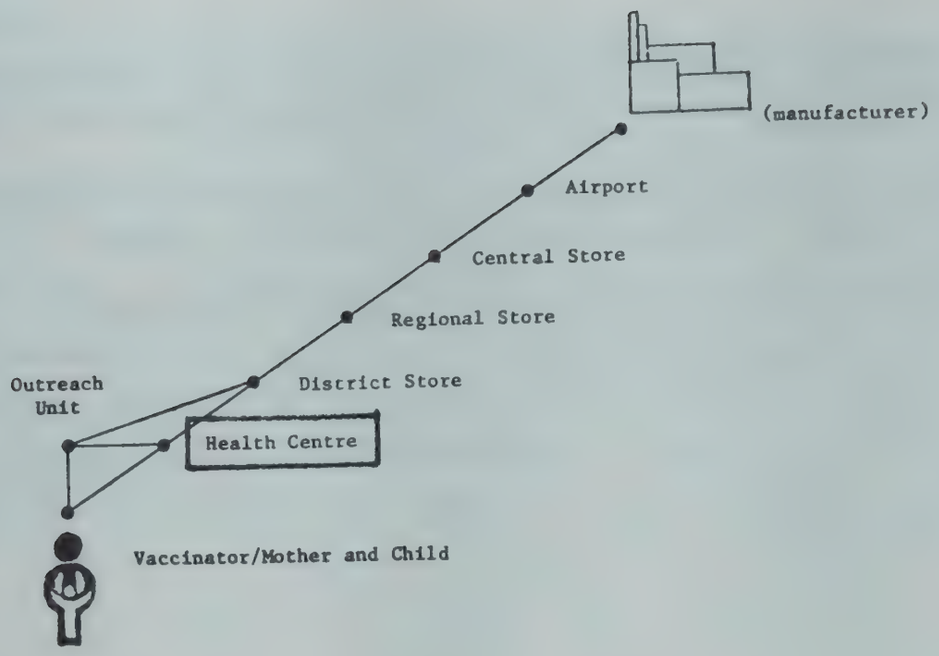
Instructions: Read the following situation and answer the questions below. Write your answers in the space provided after each question.

Situation: While traveling to an outreach site, you accidentally drop your flask. The glass breaks into many tiny pieces.

Questions: 1. What would you do with the vaccine in the flask?

2. How would you try to prevent this problem from occurring again?

When you have completed this exercise, consult a course manager to discuss your answers to Exercises B, C, and D.



2.0 HEALTH CENTRE AND THE COLD CHAIN

As a health centre manager, you have many responsibilities. One such responsibility is managing the cold chain. Although you may delegate some of your duties to others, the final responsibility for ensuring that the cold chain operates efficiently and effectively is yours. Your major duties are:

2.1 Obtain vaccines.

2.2 Maintain equipment.

2.3 Maintain vaccines.

These responsibilities may also apply if you are involved in outreach activities. They are described in detail below.

2.1 Obtain vaccines.

You will either collect vaccines from the district or regional store or from someone who delivers them to your health centre.

It is best if you collect vaccines at regular intervals. For example, you might collect vaccine once a week or once every two weeks. However, you should not collect vaccine at intervals greater than once a month. This is because it is recommended that vaccine be stored no longer than one month at the health centre.

It is important that you obtain the right amount of vaccine. If you obtain too little vaccine, you may cause delays in your immunization activities. If you obtain too much vaccine, some of it may expire or it may be kept longer than the recommended time.

The following procedure can be used to estimate the amount of vaccine you need to collect.

2.1.1 Estimate the number of children under 1 year of age this year.

Multiply the total population of the area times the percent (expressed as a decimal) of the total population under 1 year of age.

Total population served by health centre this year	X	Percent of total population under 1 year of age	=	Total population under 1 year of age this year

For example, suppose that the total population served by your health centre this year is 10,000. Further suppose that the percent of this population under 1 year of age is 3%, or 0.03 when expressed as a decimal. In this example, the total population under 1 year of age this year is 300.

$$10{,}000 \times 0.03 = 300$$

2.1.2 Estimate the number of children to be vaccinated this year.

Multiply the total population under 1 year of age this year (from 2.1.1) times the percent (expressed as a decimal) of coverage expected.

Total population under 1 year of age this year	X	Percent of coverage expected	=	Number of children to be vaccinated this year

To continue the example in 2.1.1, if the expected coverage is 80%, or 0.80, the number of children to be vaccinated this year will be 240.

$$300 \times 0.80 = 240$$

2.1.3 Determine the number of doses of each vaccine you will administer this year.

Multiply the number of children to be vaccinated this year times the number of doses of each vaccine to administer to each child.

Number of children to be vaccinated this year	X	Number of doses of vaccine to administer to each child	=	Number of doses of vaccine to be administered this year

You will need to determine the number of doses to be administered for <u>each</u> vaccine. The following sample immunization schedule may be helpful.

Vaccine	Age at First Dose	Number of Doses	Minimum Interval Between Successive Doses
BCG	Birth	1	-
DPT	3 months	3	1 month
Polio	3 months	3	1 month
Measles	9 months	1	-
Tetanus	15 years (women)	2	1 month

Figure 7. Immunization Schedule

In our example, you will administer 720 doses of DPT vaccine.

$$240 \times 3 = 720$$

2.1.4 Determine the number of doses of each vaccine you will actually need this year. You will always need more vaccine than you plan to administer. This is because opened vials that still contain vaccine must be thrown away at the end of a vaccination session.

a. Divide the number of doses of each vaccine you administered last year by the number of doses with which you were supplied.

Number of doses of the vaccine administered last year	÷	Number of doses of the vaccine supplied last year	=	Vaccine administration rate

For example, if you were supplied with 500 doses of DPT last year, but you actually administered only 300 doses, your vaccine administration rate would be 60% or 0.60.

$$300 \div 500 = 0.60$$

b. Divide the number of doses of each vaccine to be administered this year (from 2.1.3) by the vaccine administration rate. (This is because you need more vaccine than you plan to administer.)

Number of doses of the vaccine to be administered this year	÷	Vaccine administration rate	=	Number of doses of the vaccine needed this year

In our example, the number of doses of DPT needed this year will be 1,200.

$$720 \div 0.60 = 1{,}200$$

Vaccine administration rates will vary with location and with vaccine. Figure 8 shows vaccine administration rates based on the combined experience of several countries. The rates in your activity may not necessarily be the same as those in Figure 8, but if they are significantly lower

you should determine the reasons why. For example, a programme might be buying 50-dose vials and only administering 20 doses per vial. Smaller dose vials might be more economical. If you are just starting your immunization activities, you may wish to use the rates below for your calculations.

Vaccine	Rates
Measles	0.75
Polio	0.75
DPT	0.75
Tetanus	0.75
BCG	0.50

Figure 8. Vaccine Administration Rates

2.1.5 Determine the number of doses of each vaccine you will need during one supply period.

The supply period is the period of time between vaccine collections. For example, if you collect vaccine once a month, your supply period is one month. The number of supply periods in one year would then be 12.

a. Divide the number of doses of each vaccine needed this year (from 2.1.4) by the number of supply periods in one year.

Number of doses of the vaccine needed this year	÷	Number of supply periods in one year	=	Number of doses of the vaccine needed during one supply period

To continue our example, if the supply period is one month, you will need 100 doses of DPT during one supply period.

$$1{,}200 \div 12 = 100$$

b. Just in case you have some unexpected demand or are not able to receive your next supply of vaccine on schedule, you should collect some extra vaccine as a reserve. A simple rule to follow is to have the amount of vaccine you need plus a reserve of 25% of that amount of vaccine. This is the maximum stock level.

Number of doses of the vaccine needed during one supply period	+	.25	x	Number of doses of the vaccine needed during one supply period	=	Number of doses of the vaccine needed during the first supply period (maximum stock level)

In our example, you would need 125 doses the first time.

100 + (.25 x 100) = 125

There are two ways of distributing vaccines. They can be (1) collected by the person who needs them or (2) delivered by the person who stores them.

If the vaccine is collected, there is no delay between the time of the order and receiving the supply as these two activities occur at the same time. If, however, vaccine is ordered you must always wait a certain amount of time before the delivery arrives. The calculation that follows is to make sure you have enough vaccine in stock for this delay.

Note: If the vaccine is collected, the calculations described in the next section (2.1.6) are not necessary.

2.1.6 Determine the number of doses of each vaccine you must order for delivery during one supply period.

The number of doses of vaccine you must order during one supply period is based on your maximum stock level (from 2.1.5) and the number of doses you expect to have in stock when the new supply arrives.

a. Multiply the average number of doses of each vaccine used in one week times the number of weeks remaining until the new supply arrives.

Average number of doses of the vaccine used in one week	x	Number of weeks remaining until the new supply arrives	=	Number of doses of the vaccine to be used before the new supply arrives

For example, if you used 25 doses of DPT each week and there are 2 weeks remaining until the new supply arrives, you will use 50 doses of DPT before the new supply arrives.

$$25 \times 2 = 50$$

b. Subtract the number of doses of each vaccine to be used before the new supply arrives (above) from the number of doses of the vaccine currently in stock.

Number of doses of the vaccine currently in stock	-	Number of doses of the vaccine to be used before the new supply arrives	=	Number of doses of the vaccine expected to be in stock when the new supply arrives

For example, if you have 75 doses of DPT currently in stock, you will expect to have 25 doses of DPT remaining in stock when the new supply arrives.

$$75 - 50 = 25$$

c. Subtract the number of doses of each vaccine expected to be in stock when the new supply arrives (above) from the maximum stock level of the vaccine needed during one supply period (2.1.5).

Maximum stock level needed during one supply period	-	Number of doses of the vaccine expected to be in stock when the new supply arrives	=	Number of doses of the vaccine needed during the next supply period

You will therefore have to order 100 doses of DPT for the next supply period.

$$125 - 25 = 100$$

In other words, upon arrival of each new supply of vaccine, you will have the estimated number of doses you need plus a reserve supply to meet unexpected need - your maximum supply level. You should also remember that you will need at least one vial for each vaccination session, and this may mean that you will have to order more than 100 doses. However, you must order <u>at least</u> 100 doses.

2.1.7 If your activity is ongoing, you can estimate your vaccine needs using your past experience. The amount of vaccine needed each supply period may vary with the time of year, expansion of activities, increased public participation, etc. To help you calculate the amount of vaccine to collect or to order you may decide to use a form similar to Figure 9 on page 28 each time you need vaccine from the district or regional store. You should give this same form to the district or regional storekeeper the next time you need vaccine.

VACCINE INVENTORY

For Supply Period

Beginning _____

Ending _____

Signature of Regional/District Storekeeper:	Name of Health Centre:				
Signature of Health Centre Cold Chain Officer:	Number of Vials				
	Measles	BCG	Polio	DPT	Tetanus
1. Balance at end of previous supply period (count in refrigerator)					
2. New supply received					
3. Balance at beginning of current supply period (1 + 2)					
4. Balance at end of current supply period (count in refrigerator)					
5. Amount used during current supply period (3 - 4)					
6. Amount needed during next supply period					
7. New supply requested (6 - 4)					

Figure 9. Sample Form

The following steps summarize the procedure just described to estimate the amount of vaccine you need to collect.

a. 5000 Total population served by health centre this year

x 0.03 Percent of total population under 1 year of age (expressed as a decimal)

= 150 Total population under 1 year of age this year

b. 150 Total population under 1 year of age this year (from Step a)

x 100% Percent of coverage expected (expressed as a decimal)

= 150 Number of children to be vaccinated this year

c. 150 Number of children to be vaccinated this year (from Step b)

x 3 Number of doses of Polio vaccine to administer to each child

= 450 Number of doses of " vaccine to be administered this year

d. 450 Number of doses of " vaccine to be administered this year (from Step c)

÷ 0.75 Vaccine administration rate for _____ vaccine

= 600 Number of doses of " vaccine needed this year

e. 600 Number of doses of " vaccine needed this year (from Step d)

÷ 12 Number of supply periods in one year

= 50 Number of doses of " vaccine needed during one supply period

f. 40 Average number of doses of " vaccine used in one week

x 2 Number of weeks remaining until new supply arrives

= 80 Number of doses of " vaccine to be used before new supply arrives

g. _____ Number of doses of Polio vaccine currently in stock

\- _____ Number of doses of _____ vaccine to be used before new supply arrives (from Step f)

= _____ Number of doses of _____ vaccine expected to be in stock when new supply arrives

h. _____ Number of doses of _____ vaccine needed during one supply period (from Step e)

\- _____ Number of doses of _____ vaccine expected to be in stock when new supply arrives (from Step g)

= _____ Number of doses of _____ vaccine to collect during one supply period.

Exercise E

Instructions: Read the following situation. Then use the procedure described on pages 29-30 to answer the questions below. Write your answer in the space provided after the question.

Situation: You are planning to travel to the regional store to collect polio vaccine for your health centre. The total population served by your health centre is 5,000. Three percent (or 0.03) of the total population are under 1 year of age. The percent of coverage expected is 100% (or 1.0). Your health centre uses the Immunization Schedule in Figure 7 (on page 22). Your vaccine administration rates are the same as those in Figure 8 (on page 24). Your supply period is 1 month. You use about 40 doses of polio vaccine in one week, and there are 2 weeks remaining until the new supply arrives. You currently have 100 doses of polio vaccine in stock.

Question: How many doses of polio vaccine will you need to collect from the regional store during one supply period?

When you have completed this exercise, consult a course manager.

Exercise F

Instructions: Read the following situation. Then use the procedure described on pages 29-30 to answer the questions below. Write your answers in the space provided after each question.

Situation: The number of children under 1 year of age in the area served by your health centre is 1,000. Your vaccination coverage target is 85% (or 0.85). You are currently halfway through a supply period of one month. The stock records show that you have a present stock of 1,500 doses of measles vaccine.

Questions:

1. Is there too much or too little measles vaccine in stock?

2. What are the possible causes for this situation?

3. What actions could be taken to correct it?

4. How can the situation be prevented from occurring in the future?

When you have completed this exercise, consult a course manager.

2.1.8 When you go to the district or regional store to collect your vaccine:

- Make sure you have enough cold chain equipment to store the vaccine you will collect (See pp. 36-50 for a description of this equipment.)
- Check that the types and amounts of vaccine and diluent are the same as you need.
- Check that the expiration date on each vial of vaccine has not passed.

  If the date has passed, do not accept the vaccine unless specifically instructed to do so by your supervisor.

- Pack the vaccine and diluent into the cold chain container quickly but properly. (See p. 8 for a description of how to pack vaccine.)
- Take vaccine and diluent to the health centre using the shortest route, and cover the distance quickly but safely.
- Transfer vaccine to cold chain storage immediately after you arrive at the health centre.

If your vaccine is delivered to you by the district or regional store:

- Confirm the arrival time through letter, telephone call, or telegram.
- See if the vaccine was kept below $+12^{o}C$ during shipment. If not, set the vaccine aside in the refrigerator and do not use it until its potency can be tested.

Note: If there is not enough vaccine to justify a test for potency (see Figure 17, p. 66), do not use the vaccine unless specifically instructed to do so by your supervisor.

- Check that the types and amounts of vaccine and diluent are the same as you need.
- Check that the expiration date on each vial of vaccine has not passed.

  If the date has passed, do not accept the vaccine unless specifically instructed to do so by your supervisor.
- Transfer vaccine to cold chain storage as quickly as you can.

2.2 Maintain equipment.

If the cold chain is to be effective, its equipment must be properly maintained. The types of cold chain equipment found in most health centres are:

A refrigerator and freezer
A cold box*
A vaccine carrier*

This equipment is designed to keep cold air inside and to prevent warm air from entering. So when you place vaccines inside this equipment, you are protecting them from the heat.

Your health centre should have at least 1 refrigerator and may have a freezer if it serves a large population. Refrigerators and freezers are of two types:

- absorption-type (powered by kerosene, bottled gas, or electricity)
- compression-type (powered by electricity)

Your refrigerator will most likely be the absorption-type, so that is the type which will be described in this section.

Refrigerators and freezers can open from the top or from the front. Top opening units have the following advantages over front opening units:

*See pp. 8-12 for descriptions of this equipment.

- retain cold air when the door is opened;
- are more strongly constructed;
- can store more vaccine per litre capacity;
- are more heavily insulated; and
- are more powerful coolers.

Most top opening refrigerators cannot freeze ice packs. Until your programme can obtain top opening units that can also freeze ice packs, your health centre should use either an additional freezer to freeze ice packs, or obtain a front opening refrigerator with a separate freezer compartment.

All cold chain equipment require routine care in cleaning and temperature monitoring. Refrigerators and freezers also require care in maintaining adequate stocks of fuel and frequently needed spare parts.

The checklists on the following pages describe how to use and maintain refrigerators and freezers, cold boxes, and vaccine carriers.

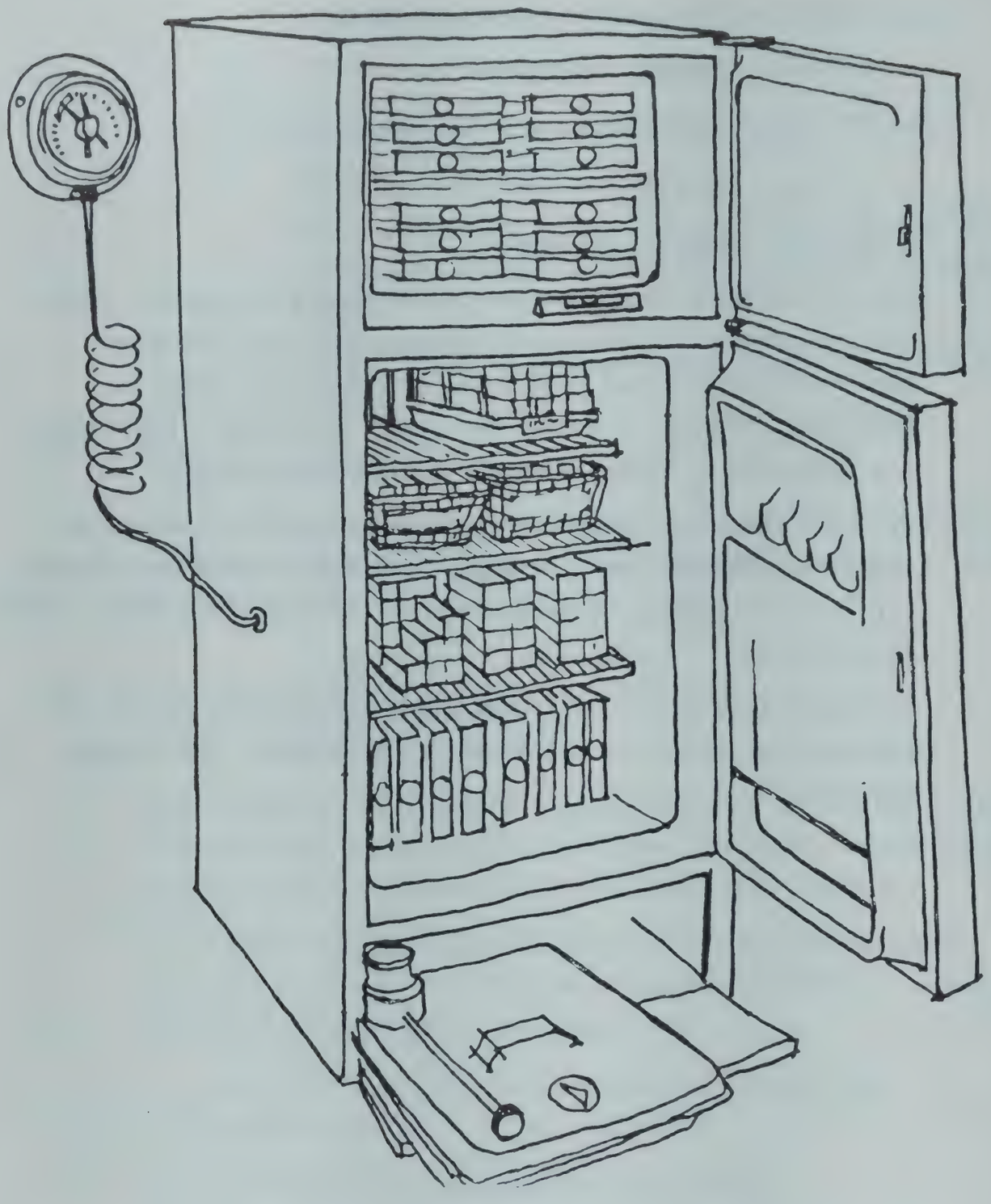


Figure 10. Absorption Refrigerator-Freezer

Use to:

- Store vaccines at temperatures above 0°C and below +8°C
- Freeze ice packs for cold boxes and vaccine carriers

- Freeze ice blocks for vaccine flasks and for cooling vaccine in a cup during a vaccination session.

To install: If you have more than one refrigerator to store vaccines, group them in one room if possible.

- Supervise the unloading of the refrigerator yourself. It is a delicate and expensive piece of equipment. It should always be handled carefully. If you have one, follow the manufacturer's instructions carefully. Keep the instructions in a safe place afterwards.

- Lock the room in which the refrigerator is located. If refrigerators have locks, lock them. If not, you can use a chain and padlock.

- Ensure that the room is well protected from outside heat.

- If several refrigerators or freezers are kept in one room, the room should be air conditioned so that heat from the refrigerators or freezers will not make the room too hot.

- Ensure that the refrigerator is level.

- If the refrigerator is electric, ensure that the connections of each piece of equipment to the electricity supply are permanent. If a plug and socket are used, tape the switches in the "on" position, and tape the plugs to the sockets to prevent accidental switching off of the supply.

- Make sure gas and kerosene refrigerators are not in a draught.

- Place refrigerators away from the wall (at least 10 cm, four inches) to allow movement of the warm air.

- Keep lids and doors firmly shut.

To pack (See Figure 11 on page 39:

- Stack vaccine and diluent neatly in rows on the top shelves of the refrigerator.

- The newest vaccine should be placed on the right side of the refrigerator. Then, when you need vaccine, take it from the left side of the refrigerator. This way you will always be sure to use the oldest vaccine first.

- Clearly separate the different types of vaccine.

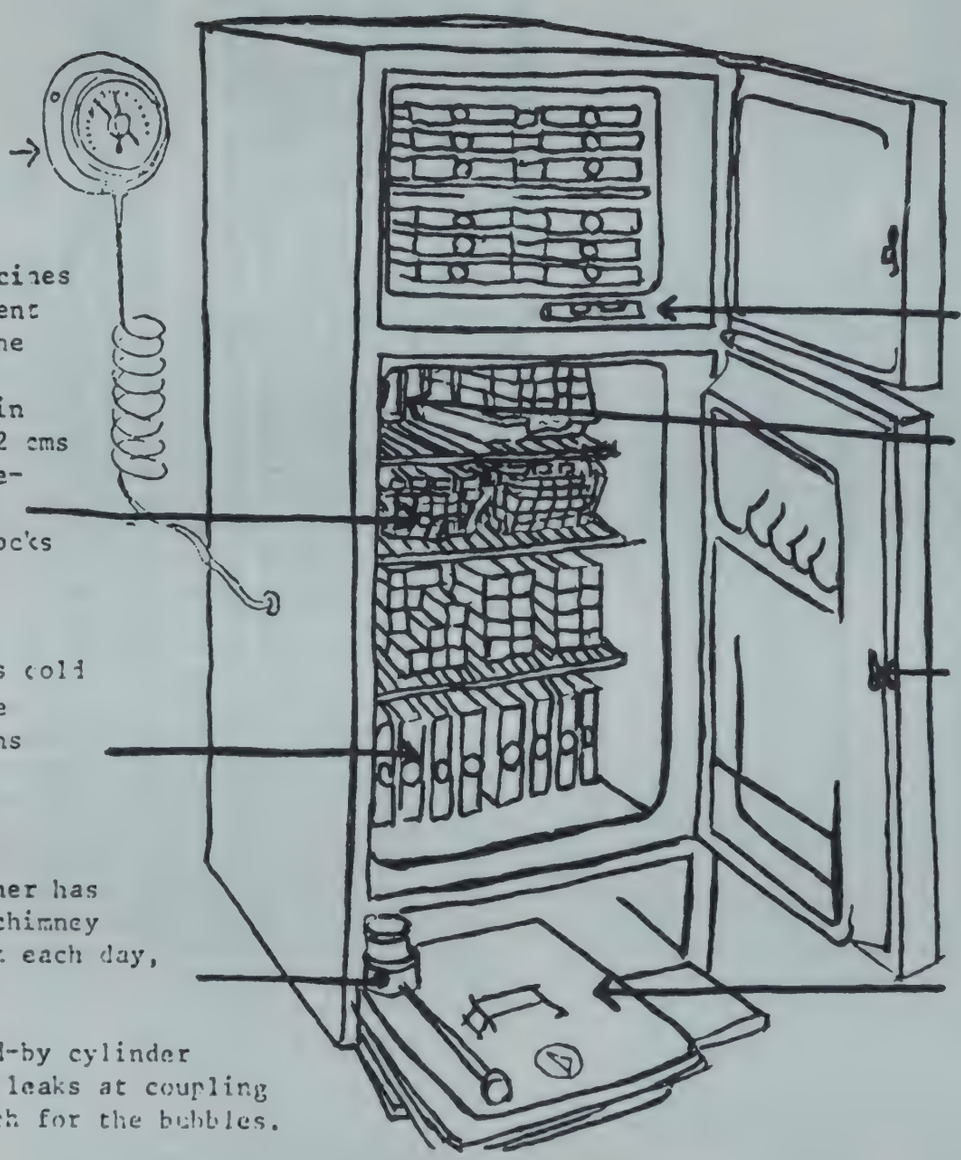
- Leave 1-2 cm between rows of vaccine to permit air movement. If vaccine is kept in trays with perforated bottoms, this will permit air movement.

- DPT vaccine should not touch the evaporator plate at the back of the top shelf of the refrigerator. It may freeze.

- Vaccine should not be kept in door compartment. The door is too warm.

- Keep ice packs in the freezer, but do not keep diluent for freeze-dried vaccines, such as measles, in the freezer. The diluent may freeze and cause the bottles to break.

- If there is empty space in the bottom of the refrigerator or in the door, place containers of water there. They will help keep the refrigerator cool if power is lost, and reduce increases in temperature when the door of the refrigerator is opened.



Dial thermometer with maximum or minimum needle and remote sensor placed among the vaccine

Separate different vaccines clearly and store diluent if there is space in the refrigerator.
Vaccine in baskets or in equal stacks spaced 1-2 cms apart to allow air movement and to facilitate counting of vaccine stocks

Extra ice packs used as cold store bottles to reduce temperature fluctuations in the refrigerator

Kerosene burner ...
Draw out only when burner has cooled to reduce glass chimney breakages. Top up tank each day, clean wick each week.
Gas burner ...
Keep at least one stand-by cylinder of gas. Check for gas leaks at coupling with soapy water - watch for the bubbles.

ALL VACCINES KEPT AT 4°C IN THE REFRIGERATOR FOR UP TO 1 MONTH, FREEZING COMPARTMENT FILLED ONLY WITH ICE PACKS USED FOR VACCINE CARRIERS AND COLD BOXES - AND TO EXTEND THE COLD LIFE OF THE REFRIGERATOR WHEN THE HEAT SOURCE FAILS...

A spirit level is placed on the base the freezing compartment to check tha the refrigerator is set level.

DPT vaccine must not touch evaporator Keep NO vaccine in the door.

Keep door tightly shut and locked.

Check that door seal is perfect - if not, it should be changed.

Fuel tank, if kerosene operated.

Figure 11. Absorption Refrigerator-Freezer

To keep in good condition:

- Kerosene absorption refrigerator
  - Refuel kerosene tank each day or check for liquid gas in the LP Gas bottle. (See pages 46-47 for detailed procedures.)
  - Filter kerosene fuel.
  - Check that the fuel tank contains fuel that looks clean and that there is no water in the tank.
  - Maintain the kerosene or gas burner each week. (See pages 45-46 for detailed procedures.)
  - Clean the flue and baffle each month, or after the kerosene burner has been smoking. (See pages 43-45 for detailed procedures.
  - Keep extra kerosene on hand.
- Gas absorption refrigerator
  - Clean the burner jet if the flame is small, yellow, and flickering.
- All types of refrigerators
  - Check that the rubber insulation seal around the door is not broken; if so, replace it.
  - Check that the door closes properly. If it does not, adjust the hinges. To adjust the hinges, loosen the screws in the hinges on the top or bottom of the refrigerator. Move the door until it closes properly. Then hold the door in its proper place and tighten the screws in the hinges. If the hinges do not adjust, find some other way to make sure the door shuts properly.
  - Order spare parts when the amount in stock reaches a previously established level. Always state the part numbers and refrigerator model number when ordering.

To maintain vaccine storage temperatures:

- Monitor inside temperature.
- Adjust the flame height or thermostat until the inside temperature is above 0°C and below +8°C.
- Keep records each day of temperatures observed. (See Figures 12a and 12b on the next page for examples of such records.)

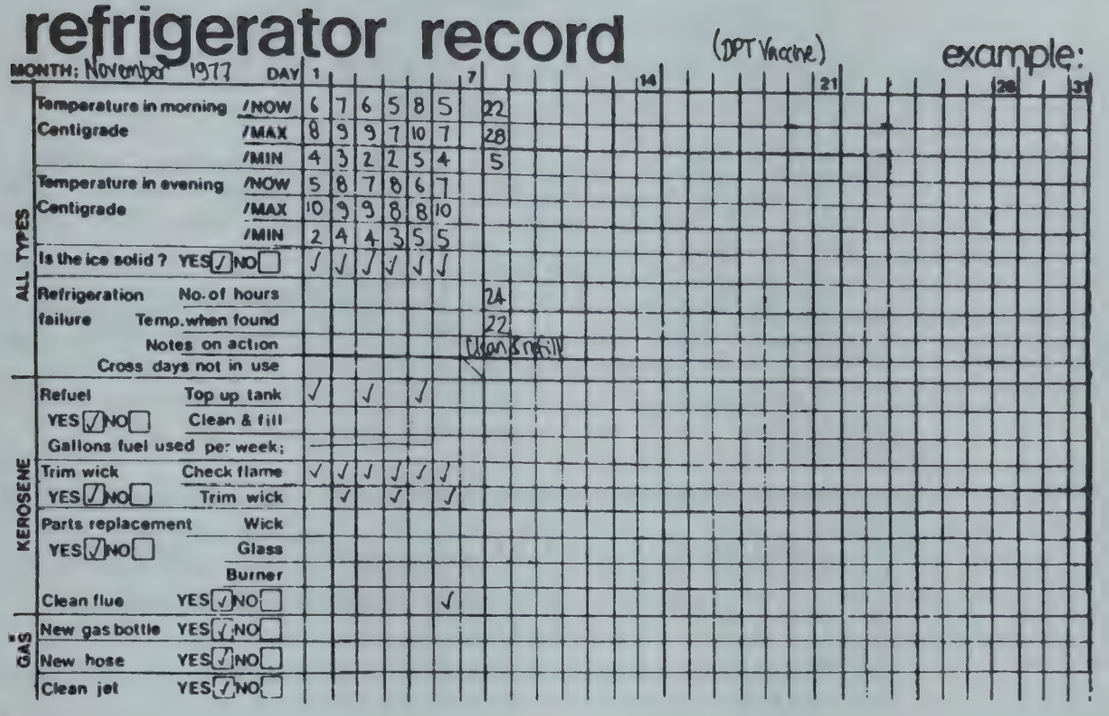


Figure 12a

REFRIGERATOR RECORD (Example)

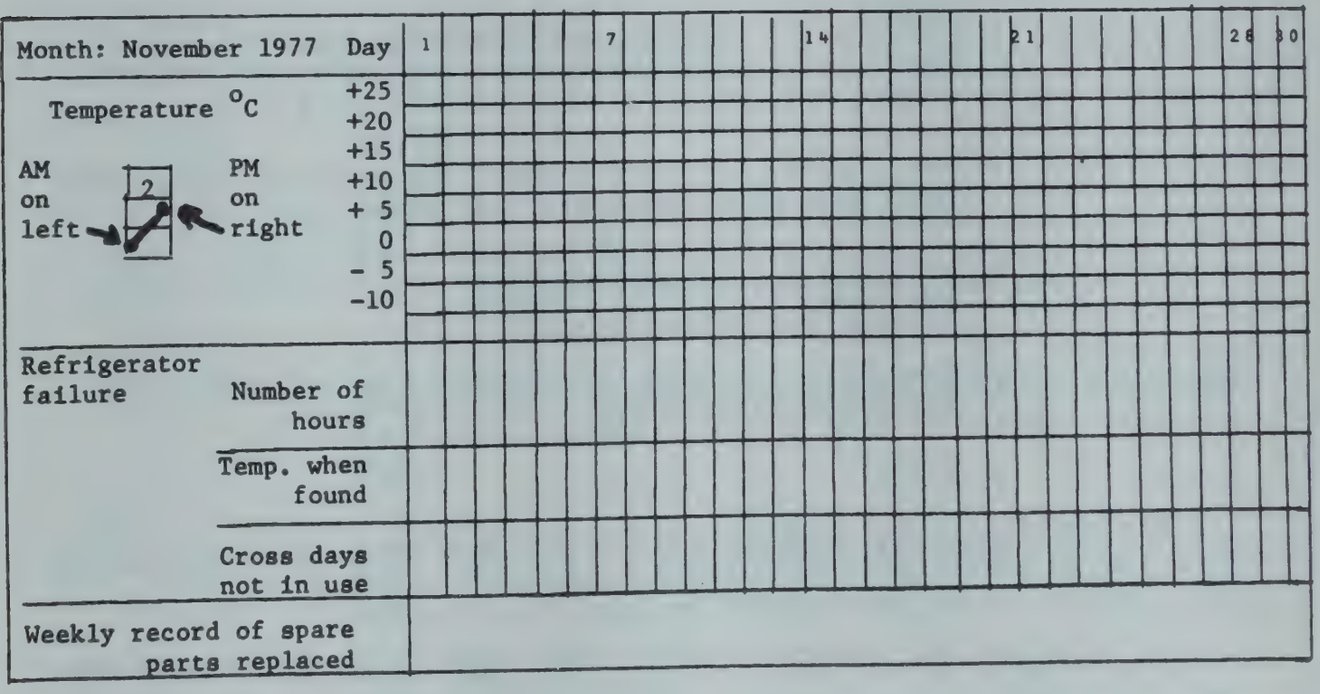


Figure 12b

- Check room temperature in very hot weather; if it is above +35°C, check the temperature in the refrigerator. If it is above +8°C, transfer vaccine to cold box with ice packs.

- Place spare ice packs or plastic bottles in all empty space in lower half of refrigerator.

- Open the refrigerator door only when absolutely necessary and for the shortest possible period of time. Plan what you will do before you open the door, then do it quickly.

To defrost:

As ice builds up in the refrigerator, it becomes WARMER, not colder, in the main part of the cabinet. If the ice in the cabinet is 5 mm thick, the unit must be defrosted.

- Transfer vaccine to another refrigerator or properly packed cold box.

- Disconnect the unit (if electric) or turn off burner (if kerosene or gas).

- Place a pot of hot water inside the unit. This will raise the inside temperature and help the ice melt faster.

- Dip a cloth in the hot water and wipe the ice. This will also melt the ice.

- When the ice is melted, clean and dry the inside of the unit.

- Reconnect the unit (if electric) or relight burner (if kerosene or gas).

- Close the door or lid.

- Return the vaccine to the unit ONLY after the inside temperature reaches +8°C.

DO NOT USE KNIVES OR OTHER SHARP OBJECTS TO SCRAPE THE ICE.

They can make a hole in the wall of the unit which may destroy it. Such holes are difficult to repair, so the unit will usually have to be thrown away.

Become familiar with your refrigerator:

If you have a kerosene refrigerator and have never used this type before, examine it carefully before trying to use it.

The upper part is the storage cabinet. It has a freezing compartment at the top which is closed by a door. There are two or three shelves in the main part of the cabinet and the main door should fit tightly. In the space under the storage cabinet is the burner. If you open the bottom door, or remove the cover, you will see the fuel tank. It is on the rails and can be pulled towards you. The tank has a filling cap and a dial to tell you the amount of fuel remaining.

The burner, which is at the far end of the tank, consists of a wick inside a short, wide glass tube. There is a rod leading to the burner which can be turned with a knob to adjust the height of the flame (see Figure 13 on page 44. At the back of the refrigerator and above the burner is a flue which projects a little way out of the top of the refrigerator. It contains a twisted piece of metal called a "baffle" on the end of a long wire hooked to the top of the flue. Lift this out when the tank is removed and clean the flue thoroughly with the brush provided.

To light the kerosene burner:

- Slide the tank out until the burner can be reached easily.
- Check that the tank is full of fuel.

  NOTE: If the tank has been empty, wait a few minutes after filling to allow the wick to become wet before lighting.
- Ensure that the fuel is filtered as it goes into the tank. Thin animal skin or felt is a most effective filter.
- Remove the glass very gently and set it down in a safe place; if a metal shield is fitted around the wick, it too must be removed before the flame is lit.
- Turn the wick up until 6 mm (1/4") is showing all around equally--this is important. Then light the wick and allow the flame to spread around the circle.


MAINTAIN YOUR REFRIGERATOR EACH WEEK!
'TOP UP EACH DAY
1 EXTINGUISH THE FLAME AND WAIT FIVE MINUTES
2 WITHDRAW THE TANK SLOWLY, CAREFULLY, GENTLY!
3 REFUEL WITH CLEAN FUEL THROUGH FILTER FUNNEL
REMOVE DIFFUSER
OR MAYBE FIT A NEW WICK ?
4 REMOVE GLASS CHIMNEY AND COPPER COLLAR
5 CHECK WICK FOR ROUGH UNEVEN EDGES
6 CLEAN WICK WITH TOOL OR BURN OFF LEVEL
7 REMOVE METAL BAFFLE FROM FLUE AT REAR
8 CLEAN THROUGH FLUE WITH A FLUEBRUSH
9 CLEAN BAFFLE AND REPLACE
ADJUST THE FLAME, WAIT 15 MINS. AND REPEAT
10 REPLACE DIFFUSER AND LIGHT WICK
11 REPLACE COLLAR AND REPLACE CHIMNEY
12 ENGAGE GLASS CHIMNEY FIRMLY UNDER FLUE

Figure 13

- Replace the glass carefully, and slide the tank back until the glass fits properly under the flue. The flame will increase in size and burn steadily if the burner is in the correct position. Remember to keep at least two spare glasses. Let the health centre supervisor know when you need more spares.

- Adjust the wick so that the flame is even, and not smoking. If you find later that the refrigerator is not cold enough, increase the size of the flame, but never allow it to smoke.

- Check 15 minutes after lighting to make sure that the wick is still burning correctly, and adjust if it is too high.

- After first lighting, it will take a day for the temperature to drop to around 4 degrees centigrade.

To maintain the kerosene burner:

- Trim the wick. Every day you should check the flame as already suggested. If the flame is not burning well, the wick will probably need cleaning or trimming. To do this, withdraw the burner from the refrigerator and remove the glass. Wait until the burner is cool before doing this. You can then turn up the wick and clean off the carbon crust which will have formed on the top edge. If the wick is burning unevenly, trim it so that it is level all the way around. You can trim the edge using the tool provided, or sandpaper.

- Change the wick. When the wick has finally burned down until it can no longer be adjusted, change it for a new one. It is necessary to unscrew the burner from the tank and feed in the new wick with the two long tails downwards. If the wick is in one flat strip, either way up will do. Fold one end into a ring and feed it into the burner while turning up the adjusting knob.

  Remember to keep at least two wicks as spares. Let the health centre supervisor know when you need more spares.

To maintain the gas burner:

- Once a week on the gas powered refrigerator, check that the burner jet is clean. You can do this by looking at the flame. If it is a steady blue flame, then all is well. But if the flame is small, yellow and shaking, the jet should be cleaned.

- Turn off the gas and remove the burner from the front or the back of the refrigerator.

- Clean the top face of the jet very gently with a clean damp cloth or a special tool if it is provided.

To check fuel supplies:

Kerosene and gas powered absorption equipment requires frequent checking of fuel supplies. The following procedures are recommended.

Kerosene Refrigerators

- Refuel the tank with kerosene each day. This lengthens the life of the wick. When you refuel the tank, remember to use the filter if one is provided; otherwise filter it with a thick cloth. Dirty fuel will keep the burner from working.

- Once each month empty the tank of fuel, rinse it out with a little clean fuel, and refill it with clean, filtered fuel. If the burner is working badly, unscrew it from the tank and look at the "tails" of the wick. If they are dirty, then you have dirty fuel in the tank. Make sure you have enough fuel in the store. Keep plenty in reserve in case you are not supplied for a long time.

Gas Refrigerators

- If you have a refrigerator powered from bottled gas, be sure to keep a good supply of gas. If you rely entirely on gas and have no standby fuel and burner, keep two bottles of gas for the refrigerator. One will supply the refrigerator while the other full bottle will be ready for use when the first one runs out.

- If you leave the health centre store for longer than one night, for example, for a weekend, check that there is enough gas left in the bottle. If it is still heavy to lift and appears to have liquid moving inside it when you shake it from side to side, it should last.

- Gas bottles should preferably be located outside the room where the refrigerator is located. They must be kept in the shade. This safety measure is most worthwhile and usually requires a simple extension of the supply line.

To change the gas bottle:

- Turn off the gas on the bottle and at the refrigerator BEFORE removing the flexible connection.

- Keep the spanner supplied for removing the flexible connection in a safe place. It must not be lost.

- Make sure that the connection of the new cylinder is very tight. The gas must not escape. Use soapy water around the joints to see if it is escaping.

- Check that the flue is clean. If it is dirty, clean it with a piece of rag tied to a string or a stick, or with the tool provided.

IF YOUR REFRIGERATOR IS NOT WORKING PROPERLY

Causes	Solutions
1. Is the freezing section frosted up?	Defrost the freezing compartment.
2. Are vaccines too close to the evaporator plate and to each other?	Move vaccines away from evaporator plate, and leave space (1-2 cms) between rows of vaccine packets to allow air to circulate.
3. Does the door not close tightly against the seal?	Replace the seal, adjust the hinges, or call a technician if necessary.
4. Is the thermometer obviously inaccurate?	Adjust the needle or ask the supervisor for a new one.
5. Is the refrigerator not completely level?	Measure by hanging a line with a weight on the end down one corner of the refrigerator cabinet. Raise the end which is too low. When the corner is vertical in both directions, the cabinet will be level. OR Measure it by placing a cup of water on top of the cabinet and making sure the water line is level.
6. Is the baffle hanging incorrectly in the flue?	Hang the baffle in the flue according to the maker's instructions.
7. Is the flue dirty?	Clean the flue with a brush, or pull a cloth through the flue several times.
8. Is the flame producing smoke?	Check that the wick is clean and trimmed. Check that the fuel is clean. If it is not, refuel the tank.
9. Is the burner or chimney damaged?	Change the burner or chimney.

	Causes	Solutions
10.	Does the burner or chimney not fit perfectly under the flue?	Check the rails supporting the tank and straighten them if they are bent.
11.	Is there not enough fuel in the tank?	Fill the tank with fuel.
12.	Is the wick dirty or used up?	Clean the wick or change it.
13.	Is the refrigerator located in a draught?	Move refrigerator or block it from the draught. Do not move it too close to the wall at the back.
14.	Is an electric fuse in the power supply blown?	Replace the fuse and identify cause of blown fuse.
15.	Is the electricity supply not at normal voltage?	Adjust the voltage if possible.
16.	Is the refrigerator unplugged?	Plug it in.
17.	Are the connections in the electric plug not secure?	Secure the connections in the plug.
18.	Is the room temperature above $+35^{o}C$?	Move vaccine to a cold box with ice packs until room temperature falls below $+35^{o}C$.

IF YOUR REFRIGERATOR STILL DOES NOT WORK PROPERLY, TRY TURNING IT UPSIDE DOWN FOR 24 HOURS. IF THIS DOES NOT HELP, CALL A TECHNICIAN.

COLD BOX

The cold box described on pp. 8-9 can be used at this level to:

- Collect vaccines from the district or regional store.
- Transport large quantities of vaccine by vehicle to outreach sites.
- Store vaccines while refrigerators or freezers are defrosting, during very hot seasons, or during a power loss.

2.3 Maintain vaccines.

2.3.1 Store vaccines properly.

All vaccine removed from the refrigerator must be used or returned to the refrigerator after the vaccination session. Vaccine that has been returned to the refrigerator unused must be used during the following session or, failing this, during the third session. If it is not used during the third session, throw it away.

To ensure that returned vaccine is selected first, place these vials on the left of the rows of vaccine in the refrigerator. Place new vaccine arriving at the start of the supply period on the right of the rows of vaccine. Always use vaccine which has been longest in the health centre first, that is, move from left to right in taking vaccine.*

If there are many people taking vaccine from the refrigerator each day, it is difficult to record the use of vaccine by each person. One method is to complete a tally card each day to record the withdrawal and return of vaccines. Another method is for each vaccinator to return the empty, used vaccine vials at the end of the day to a bag or box marked with the name of the vaccinator responsible. At the end of a chosen period, the vials can be counted and recorded. Another possibility is to allow only one person to take vaccine from the refrigerator. Anyone needing vaccine would get it from this person, who would be responsible for keeping records.

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* Sometimes, you may receive new vaccine which will expire before the vaccine already in your refrigerator. If this happens, use the newly arrived vaccine first.

2.3.2 Monitor temperatures.

The temperature at which vaccine is stored should be monitored in order to:

- record any mishandling of vaccine
- check that equipment is working properly

In addition to monitoring, an essential element of the system is recording. The system of temperature monitoring should have both automatic recording equipment and procedures for manually recording the temperature.

At health centre (and district/regional) stores where freezers or refrigerators may be used, attach dial and remote sensor thermometers to each unit. (See Figure 14.) Ensure that the dial is on the wall of the room, and that the sensor is inside the storage area. Place the dial so that it can be easily seen and the temperature recorded without opening the lid or door of the vaccine store. Record internal temperatures each day on refrigerator forms such as those in Figures 12a and 12b on page 41.

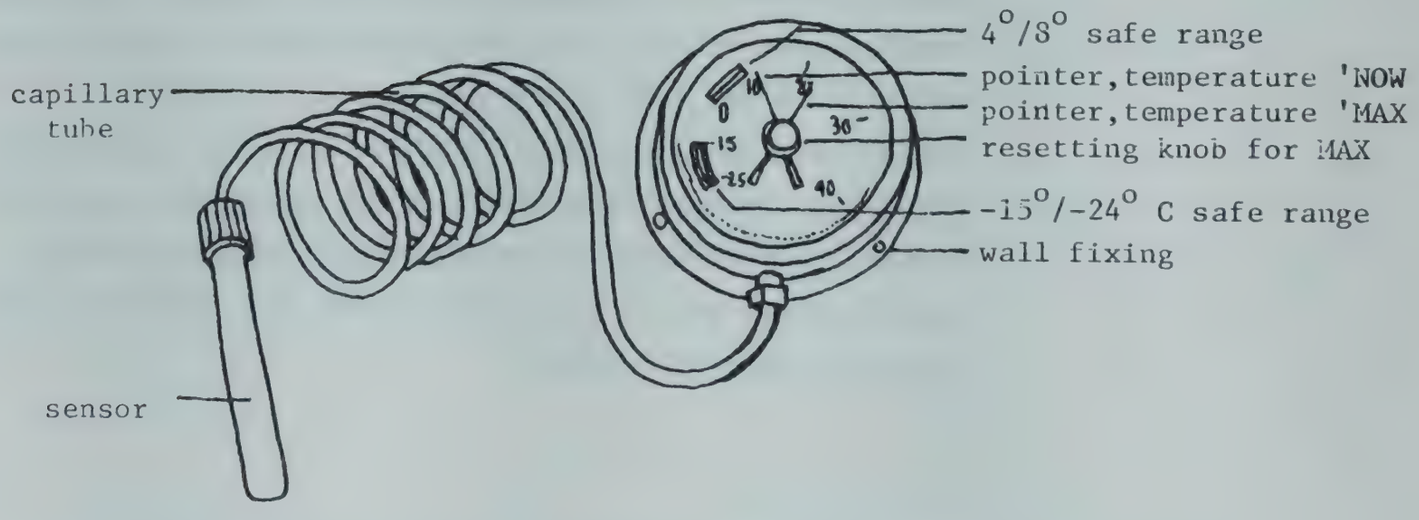


Figure 14. DIAL AND SENSOR THERMOMETER

Reset the red maximum temperature pointer after each reading by twisting the central knob until it rests gently on the upper right surface of the black needle. The next time that you read the thermometer, the red needle will give the highest temperature reached during the period between readings.

The thermometer is available with alarm contacts to operate an alarm system.

For health centre and district stores, the same dial and remote sensor thermometers are preferred, but the version without alarm contacts is usually more suitable. Alternatively, if dial and sensor thermometers are considered too expensive (about US $50), then stem thermometers or cheap bi-metal internal thermometers can be used (See Figure 15).

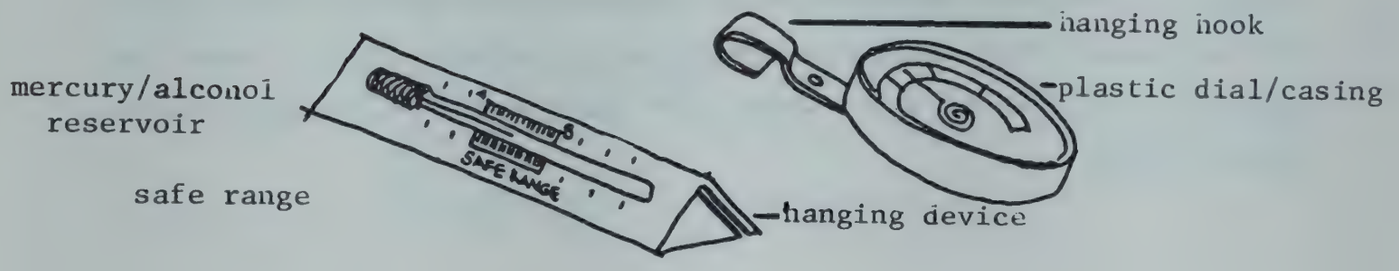


Figure 15. STEM THERMOMETER BIMETAL THERMOMETER

Here are some suggested ways of using the information given by thermometers--but a word of warning! Most thermometers react slowly; measurements can only be taken after 15 minutes have elapsed to allow the refrigerator to recover and the pointer to stabilize.

- Check temperature distribution by measuring the temperature in the top and the bottom of a piece of vaccine storage equipment. You may find warm areas in which vaccines should not be stored.
- Check minimum temperature reached overnight. Even with electric compression refrigerators, if the thermostat is set to maximum, the lower outside temperature at night can cause the inside temperature to drop below $0^{o}C$. This endangers DPT vaccine.
- Check the maximum temperatures reached on working days. If they are high, this is probably due to opening the door too often. Using the thermometer, it will be possible to determine how many openings can safely be made on a hot day and how long the refrigerator door should be kept open. High maximum temperatures can also be due to inserting quantities of food or drink which have been stored at outside tropical temperatures.

Exercise G

Instructions: Read the following situation and answer the questions below. Write your answers in the space provided after each question.

Situation: Your kerosene refrigerator is working but is not cold inside. The temperature inside the refrigerator is +20°C.

Questions: 1. What are five likely causes of this problem?

Not defrosted

2. [illegible] not burning well

3. Absorption of fuel [illegible]

4. Not cleaning tank when dirty or water with

2. What would you do to resolve each cause?

Defrost [illegible]

Burn well, clean tank regularly

Add [illegible]

3. How would you try to prevent the problem from occurring again?

Exercise H

Instructions: Read the following situation and answer the questions below. Write your answers in the space provided after each question.

Situation: Your health centre, one day's journey by public transport from the regional store, runs out of kerosene for the vaccine refrigerator. There is no kerosene to be found in the village. The nearest supply is in the regional capital. There is a cold box in the health centre which, when fully loaded with cold packs, has a cold life of 5 days and a vaccine capacity of 6 litres. But you find that you have 10 litres volume of vaccines (2 litres BCG, 2 litres polio, 3 litres DPT, 1 litre measles, 1 litre smallpox, and 1 litre tetanus), and in the ice-making compartment you have only 3 half-litre ice packs in a frozen state.

Questions: 1. What actions would you take to best protect the vaccine?

2. What questions would you ask when investigating the failure?

3. What actions can be taken to prevent the problem from occurring again?

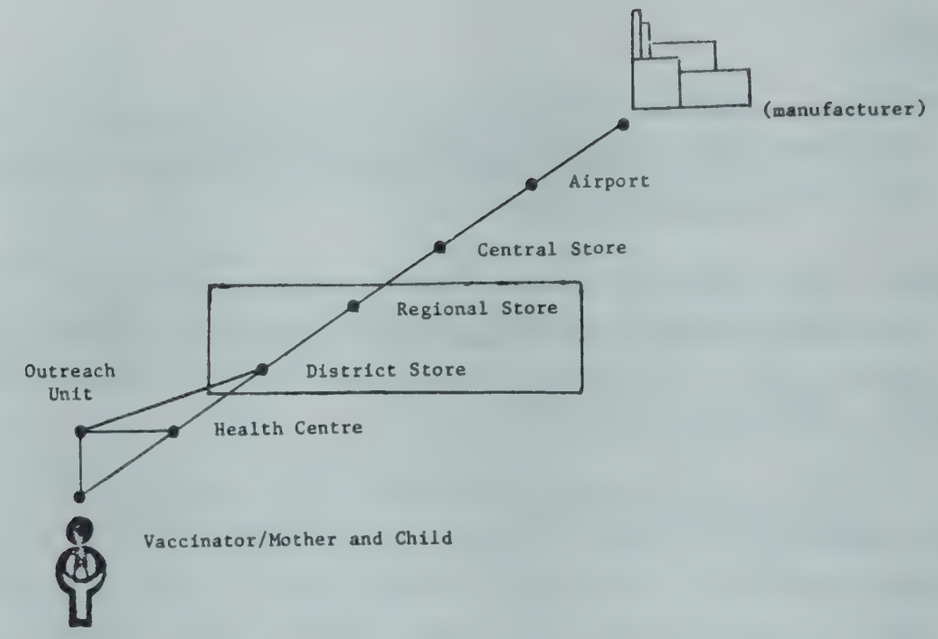
Exercise I

Instructions: Read the following situation and answer the question below. Write your answer in the space provided after the question.

Situation: The regional store informs your health centre that it will not be able to deliver the vaccine you need on schedule.

Question: What would you do?

When you have completed this exercise, consult a course manager to discuss your answers to Exercises G, H, and I.



3.0 DISTRICT/REGIONAL STORE AND THE COLD CHAIN

Some immunization programmes have either district or regional stores; some have both. In any case, the cold chain responsibilities at the district and regional levels are very similar. Therefore, they will be discussed together in this section. The word "regional" will be used to refer to both the regional and district levels.

As a regional manager, you have many responsibilities. One such responsibility is managing the cold chain. Although you may delegate some of your duties to others, the ultimate responsibility for ensuring that the cold chain operates efficiently and effectively is yours. Your primary duties are:

3.1 Obtain vaccines.

3.2 Maintain equipment.

3.3 Maintain vaccines.

Each of these responsibilities is described in detail below.

3.1 Obtain vaccines.

You will need vaccine to distribute to health centres in your region and to outreach units that operate out of your store. You will request needed vaccine from the central store. The central store will

usually then make arrangements to deliver this vaccine to you. It is best if you collect vaccines at regular intervals. For example, you might collect vaccine once a month or once every two months. However, you should not collect vaccine at intervals greater than once every three months. This is because it is recommended that vaccine be stored no longer than three months in the regional store.

It is important that you obtain the right amount of vaccine. If you obtain too little vaccine, you may cause delays in your immunization activities. If you obtain too much vaccine, some of it may expire or it may be kept longer than the recommended time.

3.1.1 The procedure to estimate the amount of vaccine you need to collect is the same as described in sections 2.1.1 and 2.1.6, pages 21-27, so it will not be repeated. The amount of vaccine involved is much greater at the district and regional levels, of course.

The following steps summarize the procedure:

a. _____ Total population in region this year

x _____ Percent of total population under 1 year of age (expressed as a decimal)

= _____ Total population under 1 year of age this year

b. _____ Total population under 1 year of age this year (from Step a)

x _____ Percent of coverage expected (expressed as a decimal)

= _____ Number of children to be vaccinated this year

c. _____ Number of children to be vaccinated this year (from Step b)

x _____ Number of doses of _____ vaccine to administer to each child

= _____ Number of doses of _____ vaccine to be administered this year

d. _____ Number of doses of _____ vaccine to be administered this year (from Step c)

_____ Vaccine administration date for _____ vaccine

= _____ Number of doses of _____ vaccine needed this year

e. _____ Number of doses of _____ vaccine needed this year (from Step d)

÷ _____ Number of supply periods in one year

= _____ Number of doses of _____ vaccine needed during one supply period

f. _____ Average number of doses of _____ vaccine used in one week

x _____ Number of weeks remaining until new supply arrives

= _____ Number of doses of _____ vaccine to be used before new supply arrives

g. _____ Number of doses of _____ vaccine currently in stock

- _____ Number of doses of _____ vaccine to be used before new supply arrives (from Step f)

= _____ Number of doses of _____ vaccine expected to be in stock when new supply arrives

h. _____ Number of doses of _____ vaccine needed during one supply period (from Step e)

- _____ Number of doses of _____ vaccine expected to be in stock when new supply arrives (from Step g)

= _____ Number of doses of _____ vaccine to collect during one supply period

3.1.2 If your activity is ongoing, you can estimate your vaccine needs using your past experience. The amount of vaccine needed each supply period will vary with the time of year, expansion of activities, increased public participation, etc. To help you calculate the amount of vaccine to collect, you may use a form similar to Figure 16 on the next page.

VACCINES CONTROL CARD

Keep these cards together in a file. Separate records for each vaccine, each type of 'doses'/container. The following is an example for countries without an existing system.

title of stores → District 3

vaccine type and doses per container → Commodity: DPT, 10 dose

NATIONAL EXPANDED IMMUNIZATION PROGRAMME			SUPPLIES CONTROL CARD		
1 District 3			Commodity: DPT, 10 dose		Vaccine Expiration Date: 2:/4/78
Date	Amount Received	Amount Disbursed	To whom disbursed or from whom received	Balance	Remarks
15/4/78	200 vials		REGIONAL STORE	200	*
22/4/78		20 vials	HEALTH CENTRE B	180	Given to Health Centre Supervisor
29/4/78	10 vials		HEALTH CENTRE B	190	Returned from Field **
					***
					****

* batch expiry date

** order book numbers

*** balance of containers in stock

**** number of containers disbursed or received

Figure 16.

Exercise J

Instructions: Read the following situation. Then use the procedure described on pages 59-60 to answer the question below. Write your answer in the space provided after the question.

Situation: You are planning the measles vaccine needs of your region. The total population in your region is 125,000. Three percent (or 0.03) of the total population are under 1 year of age. The percent of coverage expected is 80% (or 0.80). Your region uses the Immunization Schedule in Figure 7 (on page 22). Your region's vaccine administration rates are the same as those in Figure 8 (on page 24). Your supply period is three months. You will have 300 doses of measles vaccine in stock when the new supply arrives.

Question: How many doses of measles vaccine will you need to collect during one supply period?

When you have completed this exercise, consult a course manager.

3.1.3 Before the vaccine is delivered to you by the central store:

- Confirm the arrival time through letter, telegram, or telephone call.
- Ensure that you have adequate storage space.

When the vaccine is delivered:

- Determine if the vaccine was kept below $-12^{\circ}C$ during shipment. If not, put the vaccine in the refrigerator, but do not use it until its potency can be tested. If there is not enough vaccine to justify a test (See Figure 17, page 66), do not use the vaccine unless specifically instructed to do so by your supervisor.
- Check that the types and amounts of vaccine and diluent are the same as you ordered.
- Check that the expiration date on each vial of vaccine has not passed.

  If the date has passed, do not accept the vaccine, unless specifically instructed to do so by your supervisor.

- Transfer vaccine to cold chain storage as quickly as you can.

When you go to the regional or central store to collect your vaccine:

- Make sure you have enough cold chain equipment to store your vaccine .
- Check that the types and amounts of vaccine and diluent are the same as you needed.
- Check that the expiration date on each vial of vaccine has not passed.

  If the date has passed, do not accept the vaccine, unless specifically instructed to do so by your supervisor.

- Pack the vaccine into the cold chain container quickly but properly.
- Take vaccine and diluent to the district or regional store using the shortest route, and cover the distance quickly but safely.
- Transfer vaccine to cold chain storage immediately after you arrive.

3.2 Maintain equipment.

If the cold chain is to be effective, its equipment must be properly maintained. The types of cold chain equipment found in most regional stores are:

A refrigerator and freezer (See pages 36-49 for descriptions)
A cold box) (See pages 8-12 for descriptions)
A vaccine carrier)

3.3 Maintain vaccines.

The objective of good vaccine handling is to minimize:

- the period of time in which all vaccines are exposed to temperatures above $+8^{\circ}C$, and some below $0^{\circ}C$.
- the period of time in which any vaccine remains in cold chain stores without being used.

This section recommends procedures of stock control and temperature monitoring which will help to achieve this objective. Recommended storage temperatures for each vaccine and maximum storage times have already been referred to in the introduction and appear in Figure 1. Information in this section will enable you to:

3.3.1 Control vaccine stocks.
3.3.2 Monitor temperatures.
3.3.3 Retest vaccine potency.

3.3.1 Control vaccine stocks.

You should know the amount of vaccine you have in storage, and be sure that the vaccine which has the earliest expiration date is used first. If two shipments of vaccine have the same expiration date, the one which has remained longest in the store should be used first.

Keep separate records of receipts of vaccine, disbursements of vaccine and a running total of the vaccine remaining in store for each type of vaccine and each size of vaccine container, by date of vaccine movement. Note the expiration date of incoming

batches and mark the arriving vaccine with the arrival date (to provide a useful check on the age of the vaccine in the store). The Vaccines Control Card (page 61) can be used to help monitor receipt and disbursement.

3.3.2 Monitor temperature (see section 2.3.2, pp. 52-54).

3.3.3 Retest vaccine potency.

Vaccine potency is tested by the manufacturer before the vaccine is sold and distributed along the cold chain. If cold chain failures occur, however, you may want to retest the vaccine's potency to see if it should be thrown away. To justify the cost of a retest, a certain number of doses of the vaccine must be involved. Figure 17 on page 66 presents useful information for deciding whether or not to retest vaccine potency. You may also retest vaccine potency occasionally to monitor the effectiveness of your cold chain. If you plan to do this, refer to Annex 3 for the proper procedures.

Vaccine	No. of doses involved justifying test	No. of doses needed for test*	Conditions of air transport	Duration of test (minimum)	Time when answer expected (allowing for repeated test)
Measles (Freeze dried) Applies also to Mumps and Rubella	1,000	50	chilled 4°C - 8°C ice packs	10 days	3 weeks
Poliomyelitis (oral) Applies also to Yellow fever	1,000	50	frozen - 20°C (solid carbon dioxide)	7 days	3 weeks
Poliomyelitis (killed)	10,000	50	chilled 4°C - 8°C ice packs	4 weeks	3 months
BCG (Freeze dried)	10,000	100	chilled 4°C - 8°C ice packs	3 weeks	2 months
Diphtheria-Pertussis-Tetanus	50,000	100	chilled 4°C - 8°C ice packs	4 weeks	2 months
Quadruple Diphtheria-Pertussis-Tetanus Polio (killed)	20,000	100	chilled 4°C - 8°C ice packs	4 weeks	3 months
Diphtheria-Tetanus Toxoid	100,000	100	chilled 4°C - 8°C ice packs	3 weeks	2 months
Tetanus Toxoid	25,000	100	chilled 4°C - 8°C ice packs	3 weeks	2 months

* Taken from at least five different locations in the store.

Figure 17. THE RETESTING OF POTENCY OF VACCINES

Exercise K

Instructions: Read the following situation and answer the questions below. Write your answers in the space provided after each question.

Situation: Assume you are a regional operations officer. You visit one of your health centres and discover that it has more vaccine than can possibly be used in the next two months. If this vaccine is stored in the health centre beyond one month, some of it will expire. The health centre's supply period is one month.

Questions: 1. What are likely causes of this surplus?

2. What actions would you take to best protect the vaccine?

3. What actions can be taken to prevent the problem from occurring again?

Exercise L

Instructions: Read the following situation and answer the question below. Write your answer in the space provided after the question.

Situation: Your regional store presently supplies two health centres in the region. The storage capacity in your regional store is sufficient for only three months' supply of vaccine for these two health centres. Two other health centres in your region have recently received refrigerators and will begin immunization activities. Immunization coverage in your region is expected to double when vaccines are supplied to these two new stores. The regional store will not be increased in capacity in time for the start of the expanded activities, and as a result there will not be adequate space to store all the vaccine.

Question: What would you do to deal with this situation?

Exercise M

Instructions: Read the following situation and answer the questions below. Write your answers in the space provided after each question.

Situation: You are responsible for the cold chain at a large regional store. You have 2 compression-type refrigerators and one compression-type freezer. You also have several cold boxes and vaccine carriers. At any given time, you have at least 5,000 doses of any one kind of vaccine in your store.

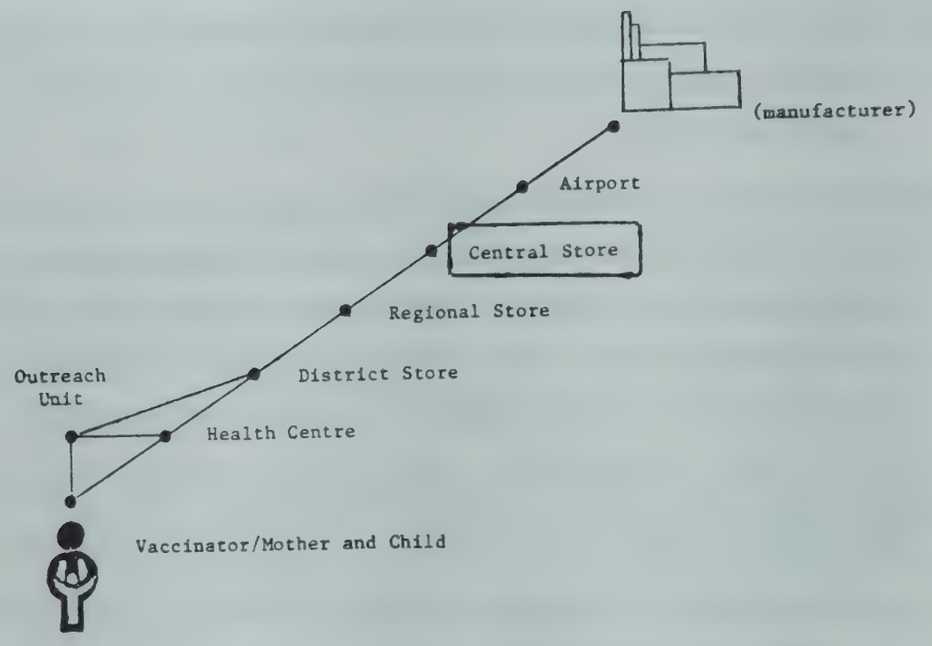
You are asked to make emergency plans for what you will do with your vaccine in the event of an electricity failure.

Questions: 1. When should you make emergency plans and what should these plans include?

2. What would your emergency plan be if the electricity will be restored within 2 hours?

3. What would your emergency plan be if the electricity will not be restored within 2 hours?

When you have completed this exercise, consult a course manager to discuss your answers to Exercises K, L, and M.



4.0 CENTRAL STORE AND THE COLD CHAIN

For most national programmes, the central store is the point along the cold chain where national vaccine needs are estimated, and where this needed vaccine is ordered from manufacturers and distributed to regional or district stores. Cold chain concerns at the central store are similar to those at the regional, district, health centre, or vaccinator levels:

4.1 Obtain vaccines.

4.2 Maintain equipment.

4.3 Maintain vaccines.

The specific cold chain activities are different, however, because contracts must be negotiated with manufacturers for the purchase of vaccines and large quantities of vaccine are being handled. These activities are described briefly on the following pages.

4.1 Obtain vaccines.

- Calculate national vaccine requirements.
- Place vaccine orders through international or bilateral donor agencies, or through direct negotiations with vaccine manufacturers.
- Obtain lowest cost vaccines which meet WHO quality standards.
- Establish timetable for vaccine delivery.
- Make sure that manufacturer can deliver vaccine without danger of vaccine losing potency.
- Make sure that arrangements are made for advance notification of exact date of vaccines.
- Make contingency arrangements in case vaccine shipment is not met.
- Ensure that adequate storage space is available to accommodate vaccine shipments.
- When vaccines arrive, ensure that they are transferred to storage area without delay.
- Check vaccines when they arrive to be sure that no cold chain failure has occurred during shipment.

4.2 Maintain equipment.

Central stores primarily use cold rooms to keep vaccines cold. Large programmes will need two cold rooms, one kept at +4°C to +8°C and one at -20°C. Smaller programs can manage with one cold room kept at +4°C to +8°C and compression-type freezers for vaccines that need to be kept frozen. Cold rooms must be provided with stand-by electricity generating equipment that automatically begins operating when normal electricity supply fails. Other cold chain equipment used by the central store will be the same as that used at other levels of cold chain.

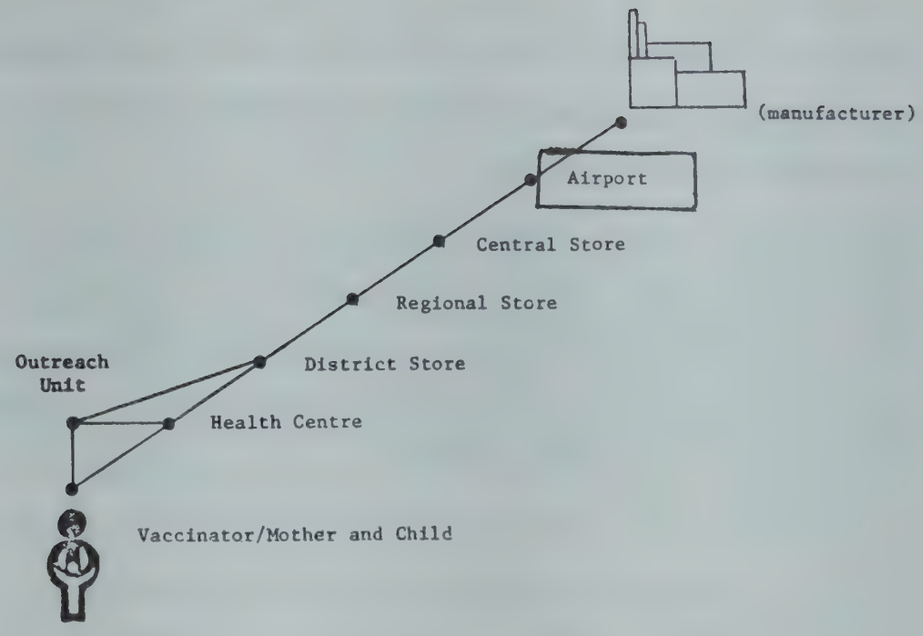
The following list includes the basic responsibilities for maintaining equipment at the central store.

- Place orders for cold chain equipment needed throughout the national programme
  - through international or bilateral donors or through direct negotiations with manufacturers.
  - for the lowest unit cost.
  - appropriate for programme needs.
- Distribute cold chain equipment, determining which types of equipment should go where.
- Follow procedures already described to maintain equipment kept at central store.
- Make major repairs of equipment.
- Throw away equipment if it cannot be repaired.

4.3 Maintain vaccines.

The risk to the cold chain at the central level should not be as great as at the vaccinator level. It is the responsibility of the central store to ensure that vaccines received and distributed have been maintained at maximum potency up to the time that they are collected by staff of regional/district stores.

- Make sure vaccines are rotated and distributed before expiration date.
- Establish an efficient vaccine distribution system that ensures smooth flow of vaccines from central store to regional/district stores, minimizing chances of cold chain failure.



5.0 AIRPORT AND THE COLD CHAIN

Most immunization programmes find it necessary to receive at least part of their vaccines through an airport. Vaccines manufactured within the country can often be delivered to the central store by vehicle, but vaccine ordered from overseas manufacturers must be delivered by air. When this is the case, the airport becomes an important link in the cold chain, joining the vaccine manufacturer and the central store.

There have been instances in many national immunization programmes where serious and expensive cold chain failures occurred at the airport. Proper coordination between the central store and the vaccine manufacturers can prevent such cold chain failures. Below is a list of activities which, if performed properly, will prevent cold chain failures from occurring at the aiport.

- Have permanent arrangements for a specific person and vehicle to meet every expected vaccine shipment.
- Arrange with airport or customs authorities to notify specific person or office whenever vaccine arrives that is not met by this person.

- If airport has cold storage facilities, arrange for vaccines to be placed in these facilities until they can be collected.
- Have necessary documents prepared in advance so that customs can be cleared without delay.
- Write advance notification arrangements into vaccine contract. Include the person, office, and address to notify and number of weeks and days in advance of arrival that notification is to be sent. Telex or telegraph address is preferred. Choose an address that will not encounter delays.

All cooling equipment has one common element--insulation. Insulation is any material which slows down the passage of heat from the warm side to the cool side. Some materials are very good insulators, such as polyurethane rigid plastic foam, and some are very bad insulators, such as most metals. Therefore, heat will pass into a box with insulated walls much more slowly than into a box without insulation. Some of the heat warming the outside surface of the box will be radiated from the sun or reflected light. This heat can be rejected by using a reflective surface on the outside surface of the insulation. But most heat flow can be reduced by increasing the thickness of most insulation materials.

Here is a list of materials from the highest standard to lower standards of insulation, compared to a standard of 100% at which no heat flow exists:

	Rating
vacuum wall	99%
rigid polyurethane foam	25%
expanded polystyrene foam	12%
cork and natural fibers	4%

Foam insulation must be dry to resist heat and for this reason only the closed cell types of foam plastic insulate well. Soft, open cell foam plastics and sponge admit vapour and allow air movement, so they are not good insulators.

Heat will not pass through a vacuum contained in the wall of a vacuum vessel. It will, however, pass slowly through the gas bubbles in polyurethane foam and twice as fast through the air bubbles of polystyrene foam.

But, heat will always pass at some speed into an insulated container until the temperature inside the insulation is the same as the temperature outside. The bigger the difference in temperatures between the inside and outside, the faster the speed of heat transfer. It is therefore always necessary to remove the heat entering an insulated container in order to maintain a lower temperature than the outside temperature.

There are two ways to remove the heat: absorb it or pump it.

Water ice is the most efficient absorber for use in the cold chain because it continues to absorb heat while it melts without rising above 0°C. The simplest form of cooling in the cold chain is the cold box. The ice packs surround the vaccine and absorb the heat as it passes into the box through the walls. The vaccine will remain at a temperature just above 0°C until all the ice is melted.

The speed at which the ice packs absorb heat is also affected by the area of the surfaces of the packs. The greater the surface area of the ice packs, the faster heat can be absorbed. If the ice packs can absorb heat faster than the rate of heat entering, then the ice melts more slowly. If the ice packs absorb heat more slowly than the heat entering, then the internal temperature will rise a little until the rate of heat entering reduces to the same as the rate of heat absorption of the ice.

Heat can also be pumped out of an insulated container by active refrigeration. The two most common types of active refrigeration are:

- absorption cycle
- compression cycle

Both types draw the heat out from an 'evaporator' and expel it into the outside environment through a 'condenser.' Although there are refrigerators and freezers which use both types of active refrigeration, many of these refrigerators only have a small evaporator. This small evaporator is usually located at the back of the top shelf, and does not surround the vaccine. This means that air must circulate among the vaccines in order to draw out the heat effectively.

Absorption cycle refrigerators are powered by heat produced by gas, kerosene, or electricity. Compression cycle refrigerators are powered by a compressor running on electricity only, and are more efficient than the absorption type in converting fuel energy to refrigeration power.

The condenser in many modern freezers is in the outer skin of the cabinet (see Figure A1.1a, page 77) and can be detected by touching the hot outer surface. Models with a separate condenser, either fan-cooled or convection-cooled, are preferred (See Figure A1.1b).

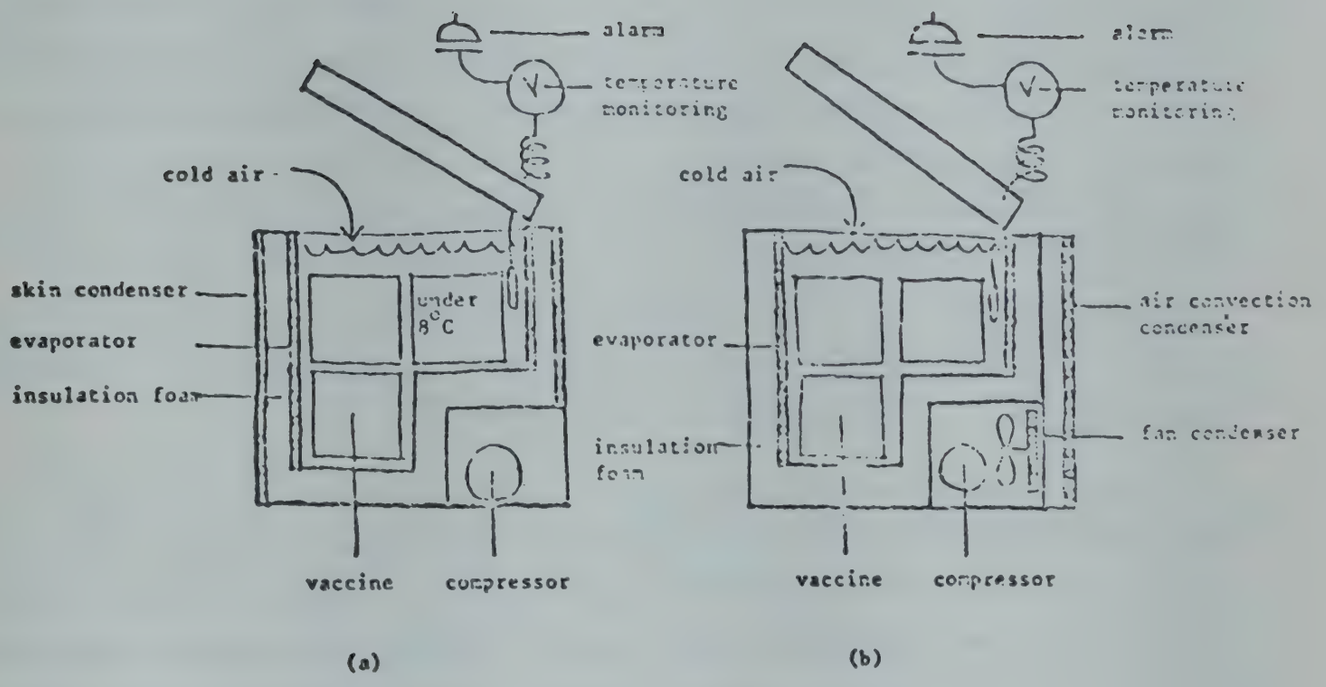

alarm
temperature monitoring
cold air
skin condenser
evaporator
insulation foam
under 8°C
vaccine
compressor
(a)
alarm
temperature monitoring
cold air
evaporator
insulation foam
air convection condenser
fan condenser
vaccine
compressor
(b)

Figure A1.

ACTIVE REFRIGERATION SYSTEMS

The compression system uses an electric motor compressor to circulate a cooling fluid called refrigerant. The pump compresses the refrigerant from a gas state into a liquid state, a process which gives off heat. Then, in an evaporator inside the freezer or refrigerator, the liquid expands, evaporates and changes back into gas, absorbing heat from the outside air. The compression system circulates the refrigerant very quickly, and thus has a much greater cooling effect than the absorption system. The temperature in the storage area is controlled by a thermostat which switches the compressor motor on and off.

The motor needs a higher power input to start than to run, but still requires a constant supply of electricity at a steady voltage. This limits where it may be used. (Voltage regulators and special generators can provide a secure supply and a steady voltage, but they are expensive.)

The absorption system uses heat produced by electricity or by burning gas or kerosene to drive a cooling cycle under pressure produced by hydrogen. The heat causes ammonia and water to circulate in a sealed system of pipes. In the evaporator inside the refrigerator, the ammonia fluid turns into a gas, absorbing heat from the inside air. As a gas it rises, circulating to the outside of the refrigerator, where it condenses into a liquid, releasing the heat to the outside air.

Absorption refrigerators are much less efficient than compression refrigerators because of the slow circulation of the fluid, but they are much more suitable for stores where there is a weak, unreliable electricity supply. There are models that can work on electricity or gas, and others that can work on electricity or kerosene.

ROUTINE ASSAY OF VACCINES FROM THE FIELD

The best way to check on the working of the "cold chain" is to assay the vaccine that has reached the end of the "chain." This is probably only worthwhile for virus vaccines such as polio and measles, but arrangements may be made in some countries for other vaccines to be assayed.

At intervals determined by the central laboratory and the programme manager, each district store and health centre in rotation should arrange to submit samples of measles and polio vaccine for routine assay. If possible, these should include samples that have already been issued to and returned to storage by teams working in the field. The returned samples should be given an identifying label.

An alternative to this is to obtain samples at random but without any fixed rotation from various district stores and mobile teams.

When the programme manager has any reason to doubt the potency of vaccine in any particular area or when he has reason to suspect that the "cold chain" is not being adequately maintained or inspected, samples of vaccine should be taken from the points most likely to demonstrate the weakness and therefore the need for remedial managerial action.

Vaccines to be tested from mobile teams or other field units should be taken from the supply of vaccines that the teams have handled in the usual way and, preferably, from the supplies remaining at the end of a particular period of work. To sample vaccines:

1. select one or two boxes of the vaccine to be assayed;
2. label clearly with the date, place, team, name of person collecting sample, etc.;
3. keep the vaccine at the correct temperature throughout the transportation back to the control laboratory. This will require careful packing and the use of refrigerators and transport;
4. notify the laboratory that samples are being sent for examination and inform them of the time and place of arrival;
5. ensure reliable transportation of the vaccines to the laboratory.

One possibility is for supervisors to take samples of vaccine during their visits to teams (especially towards the end of the team's stay in the field) and arrange for the samples to be forwarded to the laboratory. With increasing confidence resulting from favourable outcomes of initially frequent, routine testing, sampling of vaccines for testing may be widely spaced and used only when specially indicated (refrigerator breakdown, etc.).

If the results of the assays of the vaccine from the field are unfavourable, then the appropriate authority should immediately examine in detail all levels of the cold chain and send further samples for assay.

GLOSSARY

Absorption-type refrigerator or freezer - powered by heat produced by kerosene, bottled gas, or electricity

Administer vaccine - give vaccine to an individual

Assay - a test of vaccine to determine if it is potent

Baffle - a twisted piece of metal on the end of a long wire hooked to the top of the flue

Cold chain - a system for distributing vaccine in a potent state from the manufacturer to the actual vaccination site

Cold chain container - insulated container used to keep vaccines cool

Compression-type refrigerator or freezer - powered by a compressor running on electricity

Diluent - liquid mixed with vaccine before the vaccine is administered

Evaporate - disappear or vanish

Flue - hole at the back of the refrigerator where heat from the burner can escape

Hinge - a flexible piece of metal on which a door or lid swings or moves

Ice packs - blocks of ice in a bag or plastic bottle which are used to keep vaccines cool in a cold chain container

Insulation - any material which keeps cold air inside a container and prevents warm air from entering

Potency - effectiveness or strength of vaccine

Potent - effective or strong

Spanner - used to remove the flexible connection before changing the gas bottle on a gas refrigerator

Thermometer - heat-sensitive device used to record temperatures

Vaccine administration rate - the percent of the total number of doses of vaccine supplied in one year that were actually administered

Wick - a bundle of soft threads used to light a kerosene burner

WORLD HEALTH ORGANIZATION
IN COOPERATION WITH
DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
CENTER FOR DISEASE CONTROL